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Achieving Interoperability Between Arden-Syntax-Based Clinical Decision Support and openEHR-Based Data Systems

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Abstract. Background: Arden Syntax is an international standard for medical knowledge representation and processing. The openEHR Foundation publishes specifications for the creation of electronic health records based on interoperable data models. Objectives: To perform a feasibility study showing how Arden Syntax medical logic modules (MLMs) can access openEHR data. Methods: Medexter's ArdenSuite was applied as an implementation of an Arden-Syntax-based clinical decision support framework, and Marand's EhrScape as an implementation of an openEHR system, for the purpose of data exchange. To assess their interoperability, we developed a use case in which ArdenSuite was connected to EhrScape; the purpose was to determine whether a patient suffers from orthostatic hypotension based on data supplied by EhrScape and decision support provided by Arden Syntax MLMs. Results: An archetype query language request was sent from an MLM to EhrScape, and the results were sent back. Conclusion: This preliminary study clearly shows that the ArdenSuite's MLMs can communicate with openEHR-based data sources.

Keywords. Health Level Seven; Electronic Health Records; Decision Support Systems, Clinical; Health Information Interoperability; Hypotension, Orthostatic.

1. Introduction

1.1. Objectives

Since a connection between the Arden Syntax and openEHR-based systems has not been reported yet in the published literature, the aim of this work was to investigate their combination and report on the experiences.

ArdenSuite [1] is a commercial solution that allows writing, compiling, and uploading Arden Syntax medical logic modules (MLMs) for clinical decision support (CDS) as well as MLM execution and integration with medical host systems and data sources. EhrScape [2] is a cloud-based openEHR platform that was used as a representative of an openEHR-based database system.

To test interoperability we established a small Arden Syntax knowledge base consisting of two MLMs. The knowledge base is used to determine whether a patient has

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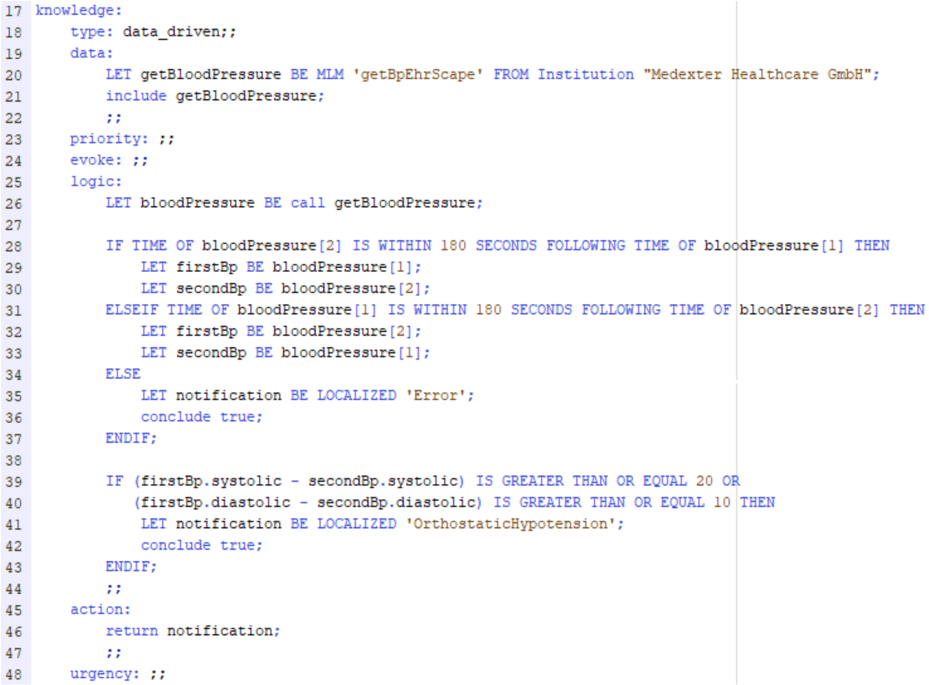
orthostatic hypotension, based on blood pressure measurements. The necessary data were taken from EhrScape.

1.2. Arden Syntax

Arden Syntax [3] is a Health Level Seven (HL7) International [4] standard for the representation and processing of medical knowledge. This standard allows knowledge to be represented in a computer-executable format and can therefore be used for the development of CDS systems [5]. Currently, HL7 International's Arden Syntax Workgroup [6] fosters the development of the Arden Syntax standard.

So-called MLMs constitute the basic knowledge elements of Arden Syntax. Each MLM contains sufficient logic to support at least one medical decision. An MLM can receive data either from input arguments, other MLMs, or via so-called read or curly brace statements from external data sources, such as an electronic health record (EHR). Figure 1 shows a code snippet of an MLM's knowledge section, and Figure 2 the corresponding medical explanation.

One advantage of Arden Syntax is that it resembles natural language (see example in Figure 1). This makes MLMs easy to write and read, even for persons with less extensive programming skills [5]. In addition, using Arden Syntax makes it easier for hospitals to share CDS knowledge packages, because they are independent of the programming language and other technical specifications used in the respective hospital's information system. Furthermore, backwards compatibility was preserved over the Arden Syntax versions [7]. As a result, knowledge packages written in an older Arden Syntax version can be used in systems with the latest Arden Syntax version, which is version 2.10 [3].



```
knowledge:
    type: data_driven;;
    data:
        LET getBloodPressure BE MLM 'getBpEhrScape' FROM Institution "Medexter Healthcare GmbH";
        include getBloodPressure;
        ;;
    priority: ;;
    evoke: ;;
    logic:
        LET bloodPressure BE call getBloodPressure;

        IF TIME OF bloodPressure[2] IS WITHIN 180 SECONDS FOLLOWING TIME OF bloodPressure[1] THEN
            LET firstBp BE bloodPressure[1];
            LET secondBp BE bloodPressure[2];
        ELSEIF TIME OF bloodPressure[1] IS WITHIN 180 SECONDS FOLLOWING TIME OF bloodPressure[2] THEN
            LET firstBp BE bloodPressure[2];
            LET secondBp BE bloodPressure[1];
        ELSE
            LET notification BE LOCALIZED 'Error';
            conclude true;
        ENDIF;

        IF (firstBp.systolic - secondBp.systolic) IS GREATER THAN OR EQUAL 20 OR
           (firstBp.diastolic - secondBp.diastolic) IS GREATER THAN OR EQUAL 10 THEN
            LET notification BE LOCALIZED 'OrthostaticHypotension';
            conclude true;
        ENDIF;
        ;;
    action:
        return notification;
        ;;
    urgency: ;;
```

Figure 1: Example snippet of the knowledge section of an MLM for orthostatic hypotension notification

Orthostatic Hypotension Notification

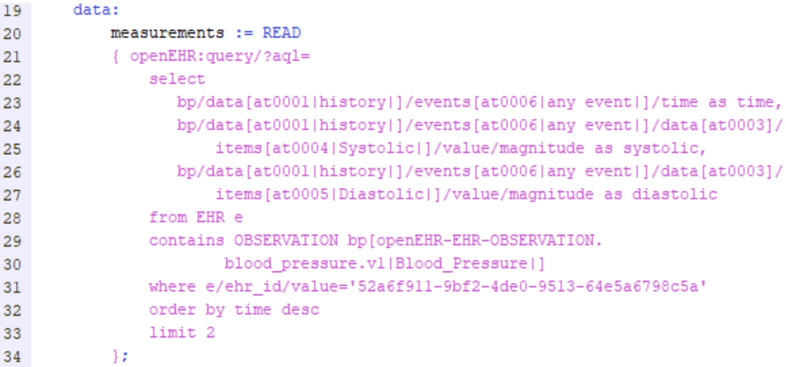
ALERT
if
Time of 2nd blood pressure measurement is within 3 min after the time of the 1st measurement
and
Systolic value of 2nd blood pressure measurement is at least 20 mmHg lower than systolic value of the 1st
and/or
Diastolic value of 2nd blood pressure measurement is at least 10 mmHg lower than diastolic value of the 1st

Figure 2: Medical explanation of the orthostatic hypotension notification MLM (see Figure 1)

1.3. OpenEHR

OpenEHR [8] is an open standard specification with the goal of turning physical health data into an interoperable digital form. To achieve this goal, the openEHR Foundation publishes specifications for the development of EHRs [9]. The openEHR approach works with multi-level, single-source modeling. 'Multi-level' means that domain experts develop models for the semantics of clinical information systems (archetypes) in their own layer, separated from the technical definitions [10]. 'Single source' means that archetypes and templates are developed independent of specific document or messaging standards. As a result, specific models (such as *microbiology results*) only need to be modeled once in order to generate reports, documents, user interface forms, representational state transfer (REST) application programming interfaces (API) specifications, or other message formats [10].

The archetype query language (AQL) [11] was specifically designed by openEHR for searching and retrieving data from archetype-based EHRs. Figure 3 shows an example of an AQL request inside a curly brace expression. Its advantage over other query languages such as SQL is that it is independent of a specific data model implementation. This is possible because the queries are expressed at the archetype (semantic) level and not at the data instance level. The minimum requirement for AQL to work is that the data is marked with the appropriate archetype codes and terminology codes. AQL queries can be sent to the openEHR server via different types of interfaces, including REST interfaces generated with openEHR templates. The openEHR specification requires that services support at least XML or JSON for data representation [12]. (However, this openEHR specification is still under development per 30 January 2018.)



```
data:
    measurements := READ
    { openEHR:query/?aql=
        select
           bp/data[at0001|history|]/events[at0006|any event|]/time as time,
           bp/data[at0001|history|]/events[at0006|any event|]/data[at0003]/
               items[at0004|Systolic|]/value/magnitude as systolic,
           bp/data[at0001|history|]/events[at0006|any event|]/data[at0003]/
               items[at0005|Diastolic|]/value/magnitude as diastolic
        from EHR e
        contains OBSERVATION bp[openEHR-EHR-OBSERVATION.
                blood_pressure.v1|Blood_Pressure|]
        where e/ehr_id/value='52a6f911-9bf2-4de0-9513-64e5a6798c5a'
        order by time desc
        limit 2
    };
```

Figure 3: AQL query within a curly brace expression of an Arden Syntax MLM that is used to request two blood pressure measurements from a specific patient in EhrScape

1.4. Orthostatic hypotension

Orthostatic hypotension [13] is a cardiovascular disorder whose prevalence in the population increases with growing age. It is diagnosed when the blood pressure of a patient drops by at least 20 mmHg systolic or 10 mmHg diastolic within 30 to 180 seconds after standing up. Symptoms include nausea, fatigue, light-headedness, dizziness, “coat-hanger” pain, visual blurring, and syncope [13]. Since the majority of patients are asymptomatic or have just a few nonspecific symptoms, a large number of cases remain undetected.

2. Methods

2.1. ArdenSuite

ArdenSuite [1] is a CDS technology platform based on the Arden Syntax standard and was developed by Medexter Healthcare [14]. The ArdenSuite integrated development and test environment (IDE) allows users to write and compile Arden Syntax MLMs. ArdenSuite supports all ArdenSyntax versions. Subsequently, MLMs can be tested within the integrated test environment. The ArdenSuite server enables access to client applications. The compiled MLMs can be uploaded to and managed by the ArdenSuite server. Via a REST or SOAP interface, external applications can call the deployed MLMs and retrieve the results. Using the ArdenSuite connectors and extensions, the ArdenSuite server can connect to different data sources such as “normal” databases (e.g., SQL) or a fast healthcare interoperability resources (FHIR) server. Additionally, there is an Activiti extension that connects ArdenSuite to the Activiti Business Process Model and Notation (BPMN) platform [15].

In this project, the ArdenSuite IDE was used for the development of MLMs to test the connection of Arden Syntax to openEHR. Besides, the Arden Syntax server in combination with the FHIR Connector were used to establish a connection with an openEHR system and execute the MLMs.

2.2. EhrScape

Marand d.o.o. company [16] developed the *Think! EHR Platform*, which is an openEHR-based EHR system. EhrScape offers an open API/open data version of this platform, which is accessible to developers in the cloud. It includes documented REST APIs [17].

Users have to register on the webpage in order to access the platform. The EhrExplorer [18] can be accessed by entering the respective account details. This is a user interface for administrating the EHR components. Managing archetypes, templates, and queries as well as executing queries are some of the functions of the EhrExplorer. The login data are also needed for the authentication of REST requests from outside the EhrExplorer.

After registration for an EhrScape access, the provided test data were searched for suitable datasets for the application of our use case (Table 1). The EhrExplorer was used to formulate a query to search the test data for patients that include the blood pressure archetype and provide a sufficient number of measurements. Furthermore, the connection from an external system and the reception of data were tested by using the freeware Postman [19] to send REST requests to EhrScape.

Table 1: Use case description for orthostatic hypotension

Title	Orthostatic Hypotension
Actors	• Physician • OpenEHR-based EHR • ArdenSuite server
Prerequisites	• An openEHR-based system that can store blood pressure measurements • The ArdenSuite server with the appropriate connectors or extensions, configured to connect to the EHR • An MLM that contains the logic for determining whether a patient suffers from orthostatic hypotension, based on blood pressure measurements
Steps	**1.** With the intention of testing the patient for orthostatic hypotension, the physician determines multiple blood pressure values while performing the bedside active standing test or the head-up tilting test [20]. **2.** The blood pressure values are entered either manually or automatically into the patient's EHR. **3.** Activated by a data-based event or a direct call by the physician, the MLM "Orthostatic Hypotension" is called from the ArdenSuite server. **4.** After successful execution of the MLM, the ArdenSuite server returns the computed conclusion.

2.3. Use case description

We developed the use case to assess the interoperability between ArdenSuite and EhrScape by retrieving and processing openEHR data (see Table 1). We created a possible workflow for orthostatic hypotension by using Arden Syntax MLMs that retrieve data from an openEHR database. Successful execution of steps 3 and 4 of this use case would indicate that the Arden Suite can connect to openEHR systems and process their data.

In step 3 of the use case, after the MLM is called the ArdenSuite server should retrieve the blood pressure measurement values from the openEHR server. After receiving these values, the MLM is executed and a conclusion is drawn according to the logic in the MLM. Step 4 serves as confirmation that the data were received and processed, and the results returned.

3. Results

After analyzing EhrScape's API explorer and testing the connections with Postman, the "/query" REST interface was chosen. This interface accepts an AQL expression as a parameter that is executed; the result is returned in the JSON or XML format. We selected the XML representation of data.

A review of the provided test data in the EhrExplorer led to the conclusion that there is enough data for testing, but additional test datasets need to be injected into the database. A patient with 27 blood pressure measurements was found. Two MLMs were written for testing the interoperability of the ArdenSuite with EhrScape and realizing the use case. The first MLM sends the data request to the EhrScape server via a curly brace expression. The curly brace expression used was "measurement := READ {openEHR:/query/?aql=…};". Here "aql=" is followed by the AQL expression for getting two blood pressure measurements from a specific patient. The whole curly brace expression with the AQL query can be seen in Figure 3. The MLM then returns the received data. The second MLM contains the logic for orthostatic hypotension (see Figure 1). It was adapted to first call the first MLM for receiving the needed data, and subsequently check for the conditions of orthostatic hypotension (see Figure 2).

For verifying the “time condition” of the orthostatic hypotension test (within 30 to 180 seconds after standing up) the time of the first measurement was takes as a reference point for standing up.

The connection of the ArdenSuite server to EhrScape was set up using the ArdenSuite FHIR connector, which is capable of sending REST requests and parse the received XML results into Arden Syntax objects. The base URL to the interfaces as well as the login data were entered in order to set up the FHIR connector. After a few minor adjustments, the FHIR connector’s internal XML reader could be used to parse the response of EhrScape to form Arden Syntax objects. Therefore, the received data can be processed in our MLMs.

Finally, the MLMs were executed successfully using data received from EhrScape.

4. Discussion

Interoperability between the platforms is useful for both parties: it allows ArdenSuite to use additional data sources for providing its CDS functions, while EhrScape would benefit by the integration of standardized CDS solutions. Further, the interoperability of the Arden Syntax standard and the openEHR standard signifies that both would benefit from a wider field of application.

The “/query” interface of EhrScape was selected for data retrieval because it takes an AQL statement as an input parameter and is therefore the most openEHR-specific one. Additionally, this interface should exist in other implementations of openEHR as well. Steps 3 and 4 of the use case were executed successfully using the test data from Marand’s EhrScape. This shows that ArdenSuite is compatible with EhrScape and also indicates its general compatibility with openEHR data.

Using the time of measurement as an indication of when the patient stood up is not an ideal solution for a real operational environment. Instead, a specialized archetype that includes information about the change of position of the patient could serve as a suitable solution.

More openEHR-based systems will have to be tested in order to further ensure the interoperability of ArdenSuite with openEHR. The clinical data repository EtherCis [21] developed by the Ripple Foundation, and the EHRServer [22] from CaboLabs are candidates for further testing because they are open-source openEHR solutions.

The openEHR Foundation is currently developing further specifications for the result structure of AQL queries [23], specifically data fields that should be used to construct the response to an AQL query in any format. This specification should be kept in mind for future adaptations of an openEHR connector for ArdenSuite.

Since the FHIR connector had to be adapted in order to establish the connection to EhrScape, we recommend the development of a specific openEHR connector in addition to the existing FHIR connector, in order to increase interoperability and provide easy-to-use connectors for different purposes.

Curly brace expressions are needed to send AQL requests to the openEHR server, as well as to retrieve and use the returned data. This shows that it is possible to connect these two standards in a way that they can communicate. In the future this may be extended to a more genuine integration of the openEHR approach in the Arden Syntax. This could possibly include the specific use of archetypes or templates in MLMs.

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