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Generation of FHIR-Based International Patient Summaries from ELGA Data

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Abstract. Patient summaries grant healthcare providers a concise overview of a patient's status. This paper showcases to which degree International Patient Summaries (IPS) represented in HL7 FHIR format can be generated using data from the nationwide Austrian Electronic Health Record system ELGA. A solution is presented which enables the automated software-assembled generation of an IPS using the FHIR Mapping Language. The generated document successfully validates against the IPS profiles. Our results show that all required IPS sections can be supplied from ELGA data.

Keywords. International Patient Summary, HL7 FHIR, HL7 CDA, ELGA, FHIR Mapping Language.

1. Introduction

Patient summaries are health record extracts comprising a standardized collection of clinical and contextual information that provide a snapshot in time of a subject of care's health information and healthcare [1]. They can help healthcare providers gain a concise overview of the patient's medical history and can be essential for the unforeseen care of patients. For this reason, patient summaries will be a fundamental component of the upcoming eHealth Digital Service Infrastructure [2] that will support cross-country health data exchange in the European Union. Patient summaries can be either written by a physician (i.e. human-curated) or be generated by software (i.e. software-assembled) [3].

In this paper we focus on the International Patient Summary (IPS) [4]. HL7 International has developed CDA and FHIR implementation guides (IGs) for the IPS. Our objective was to examine to what extent an IPS can be generated from existing health data stored within the Austrian national electronic health record (EHR) system ELGA [5]. At this point, seven different document types (i.e. "Medication Summary", "Physician Discharge Summary", "Nurse Discharge Summary", "Nurse Transfer Note", "Laboratory Report", "Diagnostic Image Report" and "Immunization Summary Report") are exchanged in CDA format through the ELGA infrastructure.

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For the generated IPS, we chose FHIR as the target format since it is the more recent HL7 standard and is also embedded progressively in more EHR systems over time. FHIR has already gained momentum in the DACH region. HL7 Germany [6] and HL7 Switzerland [7] have defined multiple core profiles based on the FHIR specification. HL7 Austria has as well started to work on an FHIR IG [8].

This paper presents the main outcomes of the first author's master thesis [9]. The entire implementation of the thesis has been made publicly available on GitLab [10].

2. Related Work

In [11] and [12] proposals have been made for the generation of software-assembled CDA-based patient summaries in the Austrian context. In [11], an automated on-demand document generation was prototyped, based on an IHE-compliant approach. In [12], ITH icoserve and Siemens Healthineers presented a prototypical approach for extracting granular information from a CDA using an Observations Broker and an Observations Extraction Service, and subsequently generating and persisting a patient summary on-demand document.

We have not found any literature that deals with compiling an IPS in FHIR format from ELGA data. However, the standardization team of ELGA GmbH analyzed to which extent an ELGA patient summary can be derived from ELGA document classes. Results were presented at the eHealthSummit in 2013 [13]. A mapping based on the presented analysis has not been implemented yet. Moreover, no projects from other countries were found in which national standardized content (i.e. from other national EHRs) was mapped to an IPS.

Although there are FHIR and CDA specifications for the IPS, a mapping between the two specifications has not been published at this point. In [14] difficulties were identified, which can arise during transformations between CDA and FHIR. Since the focus of our work is the mapping from multiple CDAs to FHIR, the paper was taken into account. Various methods exist for mapping between CDA and FHIR. It should be noted that converters are only available between C-CDA and FHIR (e.g. FHIR converter from Microsoft [15] and HL7 [16], as well as fhir2ccda [17] and cda-fhir [18] from Amida Technology Solutions). To this point, there is no converter, which can generically convert between CDA and FHIR. Manual mapping is required for a conversation between CDA and FHIR since the sources can differ depending on national circumstances and the document type itself.

There are multiple projects, which dealt with conversions between both formats. In [19], an e-medication CDA has been successfully converted into FHIR resources with a JSON-based mapping. Furthermore, [14] and [20] have also showcased how a mapping could be established using an XSL transformation. [21] showed how e-medication CDA documents can be transformed into FHIR documents and back, using the FHIR Mapping Language (FML). In the course of our work, the FML was chosen as the mapping method for generating an IPS in FHIR format, since it is a part of the HL7 FHIR specification and is already applied in the Draft FHIR IG of HL7 Switzerland [7]. Alternatively, the Whistle Data Transformation Language [22] can also be used for mapping purposes.

3. Methods

The presented approach is based on the FML and maps CDA input to FHIR output. It enables the automated generation (software-assembled) of an IPS using Python or HTTP scripts. The transformation itself is triggered by HTTP requests inside the scripts. For easy deployment, we used only FHIR servers, which are publicly available as Docker containers.

When populating the different IPS sections, data from multiple ELGA documents have to be retrieved. As the REST/FHIR APIs can only handle one input file, we had to merge the set of required ELGA documents into one single XML file. As our source data, we relied on CDA test documents from the ELGA GmbH GitLab [23]. Only fully structured Level 3 CDAs were used.

For the implementation work, Visual Studio Code was found to be a useful tool as it supports several FHIR-related tasks via plugins (e.g. FHIRPath, JSON-to-XML-converter, FHIR validation, execution of HTTP scripts).

Our approach was tested using FHIR R4, IPS IG version 1, ELGA IG version 2.06.1, and V2.06.2, as well as Austrian e-immunization version 1.1.1. Should there be any changes to the IGs, the provided IPS mapping may need to be updated alongside.

3.1. Mapping paths

Mapping paths (i.e. for the use with FHIRPath) play a fundamental role in defining the rules for mapping ELGA CDAs into an IPS FHIR Bundle. In the IPS profiles, mappings to other standards are provided. Unfortunately, no mappings are provided to the CDA standard currently. Using the specifications from ELGA and IPS, we therefore had to identify the required structural and terminological transformations. The mapping paths were used for the definition of the FML mapping rules.

3.2. FHIR Mapping Language

The FML is part of the FHIR specification [24] and allows the definition of mappings from one data model to another data model. Using mapping files, it is described in a declarative fashion how the input (e.g. ELGA CDAs) is to be transformed. Besides structural transformations, also mappings between different terminologies used in the source and target models can be specified by means of ConceptMaps. The defined mapping files need to be uploaded to a FHIR server that acts as the mapping engine, i.e. it must support the mapping workflow ($convert and $transform operations). By uploading the mapping files to a mapping engine, they are automatically converted to StructureMap resources. These resources can then be processed by the mapping engine. Clients can trigger transformations through HTTP requests. Matchbox [25] is an example of a FHIR server, which supports the functionality of a mapping engine.

3.3. Validation

We validated the generated FHIR-based IPS against the IPS Bundle profile by means of the Inferno Validator [26], a web app for FHIR resource validation. Depending on the used Validator and its supported terminologies, the validation results may differ.

4. Results

4.1. Transformation workflow

Figure 1 shows an overview of the FHIR-based approach for the generation of the IPS:

1. The relevant source documents (ELGA data from a specific patient) are taken as input by the mapping service.
2. The source documents are passed to the mapping engine. In this step, the mapping engine transforms the source documents into a FHIR-based IPS (i.e. Bundle resource) based on the specified maps.
3. As soon as the transformation is done, the FHIR Bundle resource is persisted in the FHIR server. The IPS can subsequently be called from the FHIR server at any time using a GET request. The Python script can be configured whether a validation against the IPS Bundle profile should be performed.

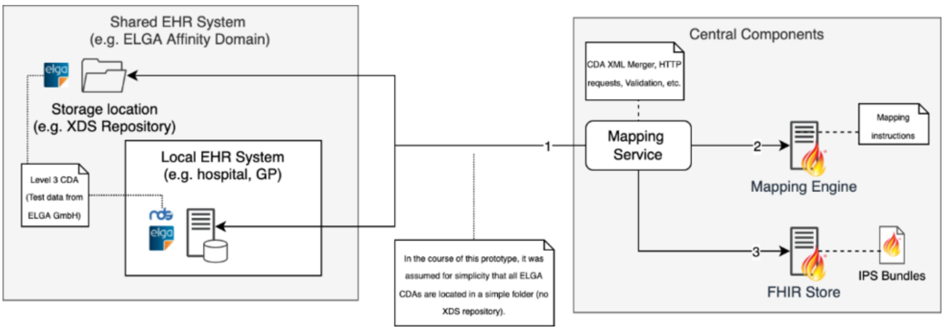

Figure 1. General overview of the FHIR-based IPS transformation.

4.2. ELGA coverage of IPS sections

The developed prototype based on the FML showcased that a valid IPS can be generated from document types that are currently available within ELGA.

Table 1 depicts to which extent the different IPS sections can be populated and which ELGA document types contain input for which IPS sections. Even though free text inputs would be available for some IPS sections, we used only structured ELGA inputs with the exception of section ”Allergies and Intolerances”. This section is required and no structured ELGA input is available currently.

After the IPS was generated, it was validated with Inferno [26]. In course of the validation, no errors were returned (only infos and warnings). Thus we conclude that a valid FHIR-based IPS can be generated from ELGA data.

Required sections	**Medication Summary**	**Allergies and Intolerances**	**Problem List**	**-**
ELGA Medication Summary	✓	⊗	⊗	-
ELGA Physician Discharge Summary	✓	○	✓	-
ELGA Nurse Discharge Summary	⊗	⊗	✓	-
ELGA Nurse Transfer Note	⊗	⊗	✓	-
ELGA Laboratory Report	⊗	⊗	⊗	-
ELGA Diagnostic Imaging Report	⊗	⊗	⊗	-
Austrian Immunization Summary	⊗	⊗	✓	-
Section is fillable	partially	partially	partially	-
Recommended sections	**Immunizations**	**History of Procedures**	**Medical Devices**	**Diagnostic Results**
ELGA Medication Summary	⊗	⊗	⊗	⊗
ELGA Physician Discharge Summary	⊗	○	⊗	⊗
ELGA Nurse Discharge Summary	⊗	⊗	⊗	⊗
ELGA Nurse Transfer Note	⊗	⊗	⊗	⊗
ELGA Laboratory Report	⊗	⊗	⊗	✓
ELGA Diagnostic Imaging Report	⊗	⊗	⊗	⊗
Austrian Immunization Summary	✓	⊗	⊗	✓
Section is fillable	partially	not fillable	not fillable	partially
Optional sections (1/2)	**Vital Signs**	**Past History of Illness**	**Pregnancy**	**Social History**
ELGA Medication Summary	⊗	⊗	⊗	⊗
ELGA Physician Discharge Summary	✓	✓	⊗	⊗
ELGA Nurse Discharge Summary	✓	✓	⊗	⊗
ELGA Nurse Transfer Note	✓	✓	⊗	⊗
ELGA Laboratory Report	⊗	⊗	⊗	⊗
ELGA Diagnostic Imaging Report	⊗	⊗	⊗	⊗
Austrian Immunization Summary	⊗	✓	⊗	⊗
Section is fillable	partially	partially	not fillable	not fillable
Optional sections (2/2)	**Functional Status**	**Plan of Care**	**Advance Directives**	**-**
ELGA Medication Summary	⊗	⊗	⊗	-
ELGA Physician Discharge Summary	○	○	○	-
ELGA Nurse Discharge Summary	⊗	⊗	○	-
ELGA Nurse Transfer Note	⊗	⊗	○	-
ELGA Laboratory Report	⊗	⊗	⊗	-
ELGA Diagnostic Imaging Report	⊗	⊗	⊗	-
Austrian Immunization Summary	⊗	⊗	⊗	-
Section is fillable	not fillable	not fillable	not fillable	-

Table 1. Overview of which IPS sections can be populated from the defined source documents.

Legend: ✓ - structured input; ○ - free text input; ⊗ - no data;
partially - at least the required elements of the section are fillable;

5. Discussion

In this work, we presented an approach that allows the generation of IPS in FHIR format from ELGA CDA documents. We were able to populate all required sections and thus a valid FHIR-based IPS document using structured ELGA data.

However, it must be mentioned that the IPS regime for the required terminologies is rather relaxed. Even though its FHIR profiles include bindings to different standardized terminologies, these are not throughout enforced. In other words, an IPS may contain codes from "external" terminologies in some of its elements and still validate against the IPS profiles.

IPS element	ELGA terminology	IPS terminology	Mapping status
Patient.gender	administrativeGender	HL7:AdministrativeGender	⊘
Patient.telecom	addressUse	HL7:TelecomAddressUse	⊘
Patient.address	addressUse	HL7:AddressUse	⊘
Medication.amount	UCUM 2005	UCUM	⊘
Condition.clinicalStatus	fixed value "completed"	HL7:ActStatus	⊘
Observation.referenceRange	observationInterpretation	HL7:ORRMC	⊘
Observation.status	(completed, aborted, active)	HL7:ObservationStatus	⊘
Medication.code	PZN	ATC / SNOMED CT	⊗
Medication.form	medikationDarreichungsform	EDQM	⊗
Medication.ingredient	ATC	SNOMED CT	⊗
AllergyIntolerance.code	free text	SNOMED CT	⊗
Condition.code	ICD-10 BMG 2017	SNOMED CT GPS	⊗
Immunization.vaccineCode	PZN / ATC / SNOMED CT	ATC / SNOMED CT / SNOMED CT GPS	⊗
Immunization.targetDisease	eImpfImmunizationTarget	SNOMED CT / SNOMED CT GPS	⊗
Observation.code	elga-LaborparameterErgaenzung / LOINC	LOINC	⊗
Specimen.type	elga-LaborparameterErgaenzung	SNOMED CT	⊗
Specimen.collection.bodySite	actSite	SNOMED CT	⊗

Table 2. Terminological mappings.

Legend: ⊘ - element was mapped; ⊗ - element was not mapped;

Table 2 shows for which of the IPS elements that include terminological bindings we were able to cover the conceptual mappings from the terminology prescribed by ELGA to the terminology prescribed by IPS. In the negative case we populated the IPS element with the original ELGA codes. As a valid IPS that still partially contains external terminologies is obviously not fully satisfying when it comes to semantic interoperability, our next task will be to also map the remaining elements from table 2. For this purpose, existing mappings between standardized terminologies will be used, such as provided by UMLS [27] or OHDSI's Athena [28].

A limitation of the FML is that it does not allow to apply where-conditions on target instances. Depending on the content of the ELGA documents, this can result in duplicate (same content but different UUIDs) resources to be generated, e.g. for specific organizations, within a Bundle. By applying where-conditions on target instances it would be possible to check if a particular resource was already generated and only add a reference in this case.

This problem could also be tackled by using a two-step approach instead of generating the complete IPS Bundle directly from the ELGA documents. Hereby, the source documents would be decomposed into their components in a first step, i.e. fine granular FHIR resources would be generated from the ELGA CDA documents. In the second step, these resources would then be composed to a FHIR IPS. This would further have the advantage that the fine granular FHIR resources could also be utilized in other contexts. Figure 2 shows a schematic solution, how this two-step approach could be realized. In any case, the mXDE [29] and QEDm [30] profiles from the IHE framework should be taken into account when considering this approach.

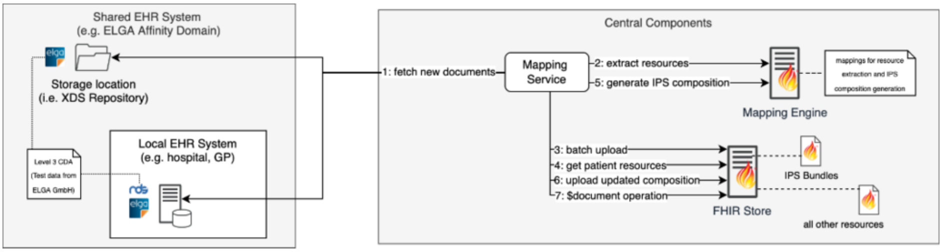

Figure 2. Two step IPS generation.

The generated IPS can be visualized in human-readable form with different tools such as IPS Viewer [31]. Until now, the generated documents have not yet been validated by clinicians, however. A corresponding validation could examine whether the mapped data within the IPS are complete and of practical value for clinicians.

6. Conclusion

This work presents an approach for generating IPS as FHIR Bundles from ELGA CDA documents utilizing the FML. Generated IPS were successfully validated with Inferno. For the creation of the mapping files, required structural and terminological transformations were identified in advance based on the existing implementation guides. Remaining limitations are the currently only rudimentary consideration of the IPS-prescribed terminologies in our mappings and the missing validation of the generated IPS for their clinical usefulness.

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