Modelling a patient identifier system in the Estonian National Health Information System

Igor Bossenko[1], Gunnar Piho[1], and Peeter Ross[2]

[1] Department of Software Science, TalTech, Akadeemia 15A, 12618 Tallinn, Estonia
[2] Department of Health Technologies, TalTech

Abstract. Accurate patient identification is crucial during admissions in healthcare institutions. Mistaken identity can lead to fatal consequences if patients are treated based on someone else's medical history. Identifying citizens is generally well-regulated, but accurately identifying foreign, unknown, or anonymous patients is more challenging and often lacks sufficient regulation. Our objective is to develop and assess a coding system for patient identifiers, enhancing the precision of associated health records and offering a robust, adaptable method for identifying patients from diverse backgrounds. We investigated the patient identifier system design in the Estonian National Health Information System (ENHIS) during its shift from the HL7 V3 to the HL7 Fast Healthcare Interoperability Resources (FHIR) communication protocols. This transition involved evolving from an Object Identifier (OID) system to a Uniform Resource Locator (URL) system. We devised an Identifier Domain coding system tailored for patient identification that aligns with our goals and generalised this system as a universal patient identification method. The Design Science methodology, a well-established approach in software engineering and information systems, underpins our research. We tested and illustrated our proposed patient identification coding system using examples from the Estonian Patient Register. This newly developed system enables the identification of all patient types. It is user-friendly, semantically clear, backwards compatible with the OID system, expandable, and aligns with FHIR standards. Our findings can assist in creating interoperable patient identifier systems internationally.

Keywords: Patient Identification Techniques · Patient Identity · Identifier Domain · Master Patient Index (MPI) · interoperability · Estonian National Health Information System (ENHIS) · HL7 Fast Health Interoperability Resources (HL7 FHIR) · Model-driven software engineering

1 Introduction

Utilising Unique Patient Identifiers (UPI) [38] is a prevalent practice across Europe, including in England, Wales, and the Isle of Man [14], as well as in Denmark [1], Spain [33], and Ireland [15]. This approach is also widespread outside Europe, in countries like New Zealand [37], China [3], and Israel [4]. UPI's are known for their distinctiveness, comparability, stability, and usability across various organisations [6]. Despite its advantages, the adoption of UPI's has faced policy barriers in some countries, such as the USA and Germany. In these regions, patient identification relies on documents like passports or driver's licenses [39].

Our paper aims to systematically design and explain a patient identification system that aligns with current standards and can be implemented in any national, hospital, or healthcare information system. This would support global interoperability in uniquely identifying patients.

1.1 Patient identification in Estonian e-health system

Our research, grounded in the documented Design Science methodology [48], examines the Estonian patient identifier system, and outlines the creation of the Estonian Patient Identifier Domain. The Estonian National Health Information System (ENHIS), a leading-edge global e-health system [9,10,30], comprehensively records health data for its citizens from birth to death.

Development of the ENHIS [35], encompassing services like discharge summaries, referrals, e-prescriptions, and electronic health records, commenced in 2005. It is built upon HL7 V3 and CDA standards, with messages defined using the HL7 Reference Information Model (RIM) and formatted in XML [41]. A pivotal element of the ENHIS is the Estonian Personal Identification Code (EstId), a national identifier for citizens and residents, essential for work, taxation, benefits, healthcare, and other government functions. The EstId is maintained by the Ministry of the Interior and issued by the Estonian Population Register.

In the ENHIS ecosystem, clinical documents reference patients using their natural identifier, such as the EstId [44].

```
<patientRole classCode="PAT">
    <id root="1.3.6.1.4.1.28284.6.2.2.1" extension="48905059995"/> ...
    <patient classCode="PSN" determinerCode="INSTANCE">
        <name> <given>Ly</given> <family>Cuusk</family> </name> ...
</patientRole>
```

Listing 1.1: Fragment of the HL7 V3 message in the ENHIS with EstId

Listing 1.1 presents a section of an HL7 V3 message within the ENHIS system, featuring an Estonian Personal Identification Code (EstId) "48905059995" [42]. This EstId format includes gender (4 for female and 20th century), year of birth (89), month (05), day (05), and a unique number (9995) for distinct identification of individuals born on the same date. This EstId appears in the "id" element's "extension" attribute. The "root" attribute signifies the namespace for EstId identifiers and is linked to an Object Identifier (OID) registry [22], adhering to the "RFC 3001 - A URN Namespace of Object Identifiers" specification [27]. The OIDs employed for patient identification are illustrated in Listing 1.2. For simplification, the ENHIS identifier (1.3.6.1.4.1.28284) is represented as "..." in this example.

```
1.3.6.1.4.1.28284 Estonian National Health Information System
 ....6 National standards
  ....6.2 Classifiers
    ....6.2.2 Technical classifiers
     ....6.2.2.1  Estonian personal identification code
     ....6.2.2.16 Personal identification codes for foreigners by country
     ....6.2.2.16.246 Personal Identification Code in Finland
     ....6.2.2.16.276 Personal Identification Code in Germany
     ...
     ....6.2.2.75 Stillborn code
    ....6.2.4 Identifiers
     ....6.2.4.7 Unknown patient identifier
```

Listing 1.2: OIDs used for patient identification in the ENHIS

For patients from abroad without an EstId, a foreign patient identification code is used, based on a document from their home country. For instance, Listing 1.3 demonstrates a foreign patient's identifier: "1.3.6.1.4.1.28284.6.2.2.16.246" is an OID for patients of the Republic of Finland, and "111111-111C" is a Finnish personal identification code [44]. An *unknown patient* refers to someone unable to provide identification at a healthcare facility, often occurring when unconscious individuals are admitted to Emergency Departments. For these patients, a unique internal identifier is assigned within the healthcare institution's namespace [44]. Listing 1.3 also shows an unknown patient's identifier, where "1.3.6.1.4.1.28284.6.2.4.7" as an OID, "90004527" representing the healthcare institution's code, and "200411111" as the internally generated patient identifier.

```
<id root="1.3.6.1.4.1.28284.6.2.2.16.426" extension="111111-123453"/>  ...(1)
<id root="1.3.6.1.4.1.28284.6.2.4.7" extension="90004527.200411111"/>  ...(2)
<id root="1.3.6.1.4.1.28284.6.2.2.75" extension="60712129993"/>        ...(3)
```

Listing 1.3: ENHIS foreign(Finnish,1), unknown (2), and stillborn (3) identifiers

1.2 Problem

Every document issued to an individual in Estonia includes an Estonian Personal Identification Code (EstId), making EstId-based patient identification in the ENHIS system highly effective for Estonian citizens. However, the Veriff database [47] indicates there are over 10,000 types of identification documents worldwide. In today's mobile world, any of these documents could serve as personal identification at Estonian healthcare institutions.

Currently, ENHIS lacks uniform rules for identifying and recording foreign patients, leading to varied practices among healthcare institutions. Some use a personal identification code, while others rely on document numbers. The diversity of documents, including various passports, ID cards, and insurance policies, further complicates the situation.

Several technical issues complicate the processing of patient IDs. One issue with the HL7 V3 and CDA documents in the ENHIS is the business restriction to use only one patient ID per document. It limits the ENHIS system from storing multiple identifiers for the same patient. Another issue is transferring patients with unknown identifiers between healthcare institutions. Typical hospital systems generate an internal identifier for such patients (Listing 1.3), appending the healthcare institution's namespace (e.g. "90001234") only when communicating with ENHIS. However, the namespace identifying the healthcare institution is not visible to end-users and is used solely for messaging.

1.3 Research questions

The ENHIS is currently shifting from an HL7 CDA document-based framework to an event-based model using the FHIR standard. Unlike the HL7 CDA's comprehensive patient data bundles, FHIR facilitates the immediate sharing of compact, modular resources at or right after a clinical event [46]. This transition includes establishing an independent Master Patient Index (MPI) registry to manage patient demographics, identifiers, associated individuals, and social history [43]. Our research aims to address several key questions in implementing the MPI with the FHIR standard:

1. Enhance message readability by replacing OIDs with more user-friendly identifier systems.
2. Develop a flexible and reliable system for registering foreign patients.

The paper is organised as follows: Section 2 details our use of the Design Science methodology to address the problems identified in Sub-Section 1.2 and the research questions from Sub-Section 1.3. Section 3 present the MPI solution in depth. In Section 4, we advocate for our proposed approach, and Section 5 summarises the research's contributions.

2 Method

We define several terms crucial to our discussion: A *namespace* is a context that provides a unique scope for identifiers, ensuring no clashes with identifiers outside of it [36]. An *identifier system* follows structured protocols to assign and manage unique identifiers [31]. An *object identifier* is an alphanumeric string that uniquely identifies an object within a particular system [32]. *Identification* refers to the process or techniques used to uniquely recognise entities, often using specific identifiers [38]. An *identifier domain* is a system or interconnected systems sharing a common identification method and authority [29]. Lastly, a *FHIR code system* is a collection of unique codes with associated meanings, standardised for healthcare interoperability [16].

In our research on creating a globally interoperable Master Patient Index (MPI) for the Estonian National Health Information System (ENHIS), we employed the engineering cycle from the Design Science methodology [48]. The process began with the evaluation/investigation phase, where we assessed the current patient identification challenges in ENHIS (Sub-Section 1.2) and explored various international solutions. This was followed by the design phase, during which we developed a proposed solution based on these global practices. Subsequently, in the validation phase, we sought feedback from key Estonian stakeholders, including the Health and Welfare Information Systems Centre, the Ministry of the Interior, the Estonian Police and Border Guard Board, and the National Institute for Health Development. Having implemented the solution in ENHIS, we are now in the monitoring/evaluation phase, observing its performance in a real-life operational setting.

3 Results

Defining an identifier system for national and regional use is not difficult. In contrast, creating identifier systems for foreigners is a serious challenge since the types of identification in another country are mostly unknown (except for a passport).

3.1 Design of the Identifier Domain

Since the number of countries, document types, and healthcare institutions is large, the solution should provide a method for updating the Identifier Domain with new identifier systems when a new country, identifier type, or healthcare provider appears. The initial idea was to design the pattern of the identifier system and validate only particular segments of the identifier system. We defined three segments to support these patterns: 1) country, 2) identifier type, and 3) organisation. The ISO 3166 standard was selected for coding the countries. The FHIR IdentifierType v2-0203[20] code system was selected for identifier types (Table 1). The country-based business or tax identifier is acceptable for the identification of organisations.

Table 2 exemplifies a multiplication of the countries and identifier types. The example contains two countries – Estonia and Germany – and two identifier types – national identifier and passport number. The identifier systems are generated automatically as a multiplication of country and identifier type. This method turned out to be too generalised. For instance, in Estonia, the passport number is not used as a patient identifier, while in Germany, there is no personal national identifier.

Therefore, we returned to the idea of a hierarchical classifier. We have deprecated the use of OID as it makes the identifier system unreadable but have kept the OID approach to creating hierarchical codes.

3.2 The URL-based Identifier Domain

We have analysed the IANA Uniform Resource Names (URN) Namespaces registry [26] and utilised RFC3043, titled “A URN Namespace for People and

Table 1: List of concepts from the v2-0203 code system used in the current paper

Code	Description
NI	National unique individual identifier
PPN	Passport number
CZ	Citizenship card (ID card)
SB	Social beneficiary identifier
BCT	Birth certificate
DL	Driver's license number
PRN	Provider number
MR	Medical record number
MRT	Temporary medical record number
TAX	Tax ID number
XX	Organization identifier

Table 2: Example of generated identifier systems managed by governmental authorities

Country	Identifier type	Identifier system
Estonia (EST)	National personal identifier (NI)	EST : NI
Estonia (EST)	Passport number (PPN)	EST : PPN
Germany (DEU)	National personal identifier (NI)	DEU : NI
Germany (DEU)	Passport number (PPN)	DEU : PPN

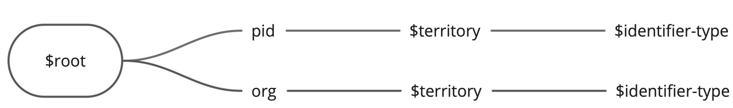

Fig. 1: Structure of the identifier system

Organizations" [28], to design our identifier systems. We also followed the HL7 recommendation [21] and used URLs for the identifier systems.

Our identifier systems (Figure 1) consist of (1) "$root", which is fixed in our solution as "https://fhir.ee/sid", where "https://fhir.ee" is an Estonian site for FHIR-based projects and "sid" is an abbreviation for "system of identifiers"; (2) "pid" as a namespace for patient/person identifiers or document numbers and "org" as a namespace for identification of healthcare providers; (3) the territory or country in which an identifier is issued; (4) the identifier type that allows values from the v2-0203 code system [20]. Table 3 exemplified URL-based identifier systems.

4 Discussion

The proposed methodology was adopted during development of the Estonian Master Patient Index (MPI). The Identifier Domain code system was developed first and then integrated into FHIR infrastructure of MPI.

Table 3: Examples of the URL-based patient identifiers

System URL	Description	Example of value
https://fhir.ee/sid/pid/est/ni	Estonian patient national identifier	37302102711
https://fhir.ee/sid/pid/deu/ppn	German passport number	C3JJ4789L
https://fhir.ee/sid/pid/ukr/bct	Ukrainian birth certificate	116326
https://fhir.ee/sid/pid/est/prn/ 90004527	Identifier issued by Parnu Hospital	123e4567-e89b a456-426614174000

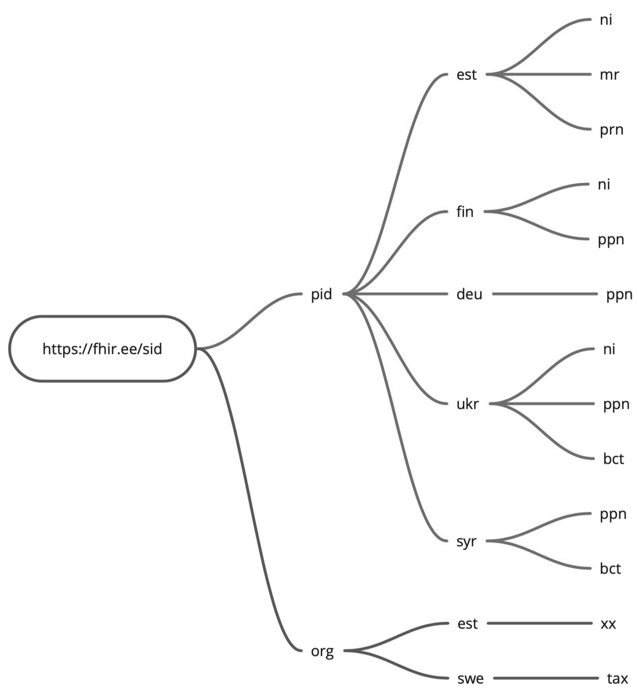

Fig. 2: Visualisation of identifier types and their subcategories in Estonia

4.1 Identifier Domain code system

The concepts of the "Identifier Domain" code system use the developed URL notation. The visualisation of some concepts in the Identifier Domain are shown in Figure 2. The code system has the additional properties of "identifier type", "country", "non selectable", and "naming system" [25]. Table 4 illustrates the fragment of the *Identifier Domain* code system. The "country" property refers to the issuer country from "iso3166-1-3" FHIR value set. The Identifier Domain supports patient identification based on eight identifier types: national identifier ("ni"), passport ("ppn"), ID card ("cz"), and birth certificate ("bct"), Estonian

Table 4: Fragment of the code system of the Patient Identification Domain

Lvl	Code	Display	Type	Country	Not Select-table	Naming System
1	https://fhir.ee/sid/pid/est	Estonian patient identifier namespace		EST	true	
2	https://fhir.ee/sid/pid/est/ni	Estonian personal identification code	NI	EST	false	https://fhir.ee/NamingSystem/pid-est-ni
2	https://fhir.ee/sid/pid/est/ppn	Estonian passport number	PPN	EST	false	http://terminology.hl7.org/NamingSystem/passportNumNS -EST
2	https://fhir.ee/sid/pid/est/mr	EE MPI Medical Record number	MR	EST	false	https://fhir.ee/NamingSystem/pid-est-mr
1	https://fhir.ee/sid/pid/fin	Finnish patient identifier namespace		FIN	true	
2	https://fhir.ee/sid/pid/fin/ni	Finnish personal identification code	NI	FIN	false	
2	https://fhir.ee/sid/pid/fin/ppn	Finnish passport	PPN	FIN	false	http://terminology.hl7.org/NamingSystem/passportNumNS -FIN

medical record number ("mr"), temporary medical number for unknown patient ("mrt"), driver licence ("dl") and provider number ("prn"). The identifier types differ by country. The "naming-system" property was added to refer to an existing instance of the NamingSystem in Estonian or HL7 repositories. The "Not selectable" property has been added for business checks. Concepts with the "Not selectable" property equal to "false" represent an active identifier, while "true" are used only to create a hierarchy. "Not selectable" concepts like "https://fhir.ee/sid/pid/fin" are not allowed to be used to identify new patients, but may be used for search with specific-country accuracy. Listing 1.4 demonstrates the search of identifier *123456* across all Finnish identifier systems.

```
Patient?identifier = https://fhir.ee/sid/pid/fin|123456
```

Listing 1.4: Search across all Finnish patient identifiers

4.2 Identifier Domain in Master Patient Index

The *Fast Healthcare Interoperability Resource (FHIR)* facilitates healthcare information exchange, supporting multiple message formats and customisable

Name	Flags	Card.	Type	Description & Constraints
Patient			Patient	
identifier	S	1..*	Identifier	An identifier for this patient
system	S	1..1	uri	The namespace for the identifier value **Binding:** Patient Identifier Domain (required)
value	S	1..1	string	Patient identification code or document number.
period		0..1	Period	Validity period of the identifier of identification document.
assigner		0..1	Reference(Organization)	Organization that issued the document. Can be used as a reference to an organization or as free text.

Fig. 3: FHIR Patient Identifier in the ENHIS

resource definitions to suit various healthcare needs [18]. FHIR profiles can be tailored for specific contexts, including mandatory elements and terminology bindings [17]. Figure 3 exemplifies a fragment of an EEBasePatient profile [23] inherited from FHIR Patient resource [19] with mandatory attributes *identifier* and *active* (because of lower cardinality is 1). The *system* attribute is bound to *the Patient Identifier Domain* value set and restricts the use of the other values, except those defined in the bonded value set.

FHIR code systems establish specific codes and their meanings. In this study, we developed the *Identifier Domain* [25] code system. Value sets are derived from one or more code systems, defining a permissible range of codes for a given context. For instance, the *Patient Identifier Domain* value set, selected from the *Identifier Domain* code system, is tailored for patient identification. Other subsets include the *Practitioner Identifier Domain* and the *Organisation Identifier Domain*.

4.3 Previous works

Many projects are working on patient identification, but a full solution is still elusive.

The eHealth Digital Service Infrastructure (eHDSI) is an infrastructure[8] ensuring the continuity of care for European citizens while they are travelling in the EU[7]. The eHDSI infrastructure is related to the "MyHealth@EU" brand [2], an electronic cross-border health service 25 EU countries plan to launch in 2025. The European Patient Smart Open Services (epSOS) project preceded the eHDSI between 2008 and 2014. Every eHDSI member country is a local data provider and has the legal status of data controller in that country[34]. Person health data may be queried from country "A" to country "B" ("pull" scenario) using the person identifiers supported by country "A", such as national personal identification code[5]. The health data "push" scenario from country "B" to country "A" is currently not functional[2], as in this scenario, cross-country patient identity management is one of the topics that must be solved first.

The Digital Green Certificates (DGC) for the European Union eHealth Network is a framework under which, in an interoperable manner, COVID-19 vaccination, testing and recovery certificates are issued, verified and accepted to facilitate persons' mobility during the COVID-19 pandemic [13]. The DGC framework was designed as a part of the European eHealth Network according to Article 14 of EU Directive 2011/24/EU. The initial data set of the COVID-19 certificate contains patient identifiers[12], but was removed from the final version of the DGC framework because some EU countries could not provide it[40].

The Patient Identifier Cross-referencing (PIX) Integration Profile is part of the technical framework of the Integrating the Healthcare Enterprise (IHE) IT Infrastructure [29]. It defines the Patient Identifier Domain as a specific healthcare information system or a space where patient identifiers are managed and associated with individual patients. The PIX profile specifies interactions and does not define any specific enterprise policies, cross-referencing algorithms, or contents the enterprise responsible for running the domain issuing patient identifiers should follow.

The European Digital Identity identifies EU citizens, residents, and businesses through electronic channels via eIDs notified under eIDAS. Using notified eIDs under the eIDAS Regulation, for the most part, will allow data providers to match an identity to an record (evidence requested) using the attributes of the natural person provided by the eIDAS minimum data set [40]. eIDs under eIDAS only cover e-channels. Furthermore, eID cannot solve the patient document-based identification problem during admission to the healthcare institution.

4.4 Changes in the patient identification in Estonia

The developed solution provides a flexible and reliable method for registering new identifier systems within the Identifier Domain code system based on context, country, identifier type and organisation. The critical differences in the proposed URL structure are readability due to the use of human-readable notation and the possibility of the automated issuing of identifier systems due to the regulated semantics of the identifier system. The Identifier Domain code system [24] was developed with TermX terminology server [45] and published as a part of the Estonian Base FHIR Implementation Guide.

Meetings were held with the Health and Welfare Information Systems Centre, the Ministry of the Interior, the Estonian Police and Border Guard Board, and the National Institute for Health Development to create a set of rules for developing the content of the Identifier Domain according to the country's laws. For example, the Estonian Police and Border Guard Board accepts the documents specified in the European Register of Authentic Identity and Travel Documents (PRADO)[11] for a person's identification when crossing the

Estonian border. In general, PRADO includes passports from all countries over the world and ID cards from EU countries. As a result of additional research, countries were identified where all identification documents contain a national identifier. Estonia, Finland, and Latvia are examples of countries where all identification documents contain a national identifier. For these countries, it was decided to support only the national identifier.

The new URL-based identifier system has human-readable format, designed for easy interpretation without needing extra tools. The attribute "root" in Listing 1.5(1) exemplified V3 OID-based patient identifier system, that is not human-readable. In opposite, FHIR attribute "system" (2) has notation that may be interpreted by human without additional vocabularies.

```
<id root="1.3.6.1.4.1.28284.6.2.2.1" extension="37302102711"/>        ...(1)
{"system":"https://fhir.ee/sid/pid/est/ni" value="37302102711"}       ...(2)
```

Listing 1.5: Patient identification in HL7 V3 (1) and FHIR (2) notations

The new MPI supports multiple identifiers for patients, enable linking and unlinking of patient records, including linking residents and foreigners and/or unknown patients.

5 Conclusion

This work is a unique attempt to standardise patient identification. On the one hand, the created solution enables the use of all documents identifying individuals and leverages already established identifier systems. Simultaneously, the solution outlines a methodology for describing national identifiers, emphasising their preference due to documents having a limited validity period, potentially resulting in unlinked records. Moreover, we present the content of the developed Identifier Domain for worldwide reuse. Lastly, we implemented an FHIR-based MPI and confirmed the successful integration of the generated IdentifierDomain with the FHIR integration framework.

This work may be used as a basis for the creation of the pan-European and worldwide Identifier Domain. Introducing a new global Patient Identifier Domain would facilitate a better understanding of which country or organisation and which type of identifier are used. This should improve patient identification worldwide.

Summary table

What was already known on the topic:

1. Patient identification is a global challenge with significant risks of treating someone based on someone else's medical history or lack of existing medical history.
2. There is currently no common regulation and method for identifying foreigners and unknown patients in Europe and worldwide.
3. HL7 FHIR is the most popular data exchange standard in the healthcare industry.

What this study added to our knowledge:

1. The Identifier Domain code system and Master Patient Index (MPI) as the solution for patient identification were built in Estonia.
2. Created a local regulation and method describing the addition of new identifier systems to the *identifier domain* to identify residents, foreigners, and unknown patients.
3. The human-readable URL-based notation with predefined grammar and predictable components is used in the Identifier Domain for identifier systems.
4. The developed solution is fully FHIR compatible.

Standard availability

The Identifier Domain code system has been published in the TermX terminology server [24] and as a part of the Estonian Base Implementation Guide [25].

Authors' contribution and acknowledgements

I.B. designed the idea and wrote the manuscript with the support of G.P. All authors contributed to the final version. G.P. and P.R. supervised the project.

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