LOINC Mapping Experiences in Italy: The Case of Friuli-Venezia Giulia Region

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Abstract: Interoperability in healthcare requires accurate data exchange and interpretation across systems, making standard terminologies essential for achieving semantic interoperability. This paper presents the approach adopted by the Friuli Venezia Giulia Region in Italy to implement LOINC, the most widely used standardized coding system for laboratory tests, into the electronic Laboratory Reports of five hospitals. Mapping was conducted manually by physicians using RELMA, supported by training and guidance from LOINC Italy experts. The validation process involved a dual-review procedure to ensure semantic accuracy but also to face issues, such as implicit or incorrect information in local catalogues and the complexity of some specialties. Collaboration among clinical staff, LOINC experts, and IT professionals proved essential in overcoming these issues. As a result, over 7,000 local tests were mapped to LOINC, and 675 new codes for unrepresented concepts were requested, thus creating a regional LOINC knowledge base. This experience highlights the importance of training, support, and integrated management in adopting LOINC, as these elements are crucial for a standardization process that enhances data traceability, minimizes errors, and supports semantic interoperability. Additionally, this experience could be an example for other healthcare systems aiming to standardize laboratory tests and achieve meaningful data exchange.

1 INTRODUCTION

Interoperability is defined as the ability of different information and communications technology systems and software applications to communicate, exchange data consistently and reuse the information that has been exchanged. In the clinical context, interoperability enables the correct interpretation of data across systems, allowing healthcare professionals, patients, and other actors to understand and act on health-related information and knowledge, even across linguistic and cultural barriers (European Commission: Directorate-General for the Information Society and Media, 2009; Iroju et al., 2013).

Clinical data interoperability is a non-trivial issue as it consists of technical, technological and semantic interoperability. It is not sufficient to have an information system or to adopt shared communication protocols, but it is necessary that the meaning of what is exchanged is not ambiguous so that it can be understood and above all reused. This translates into a single word: semantic interoperability. To this aim, the implementation of standardized terminologies is critical for effective knowledge management in healthcare domain.

The use of specialized vocabularies and terminologies addresses the challenges posed by the lexical complexity and the high level of specificity of the "medical jargon"(Gotlieb et al., 2022). Medical standardized terminologies not only facilitate the seamless sharing of information among different healthcare institutions, but also ensure that intended meanings are preserved throughout the entire clinical workflow, eliminating ambiguity, controlling synonyms or equivalents, and establishing explicit semantic relationships. These systems serve as

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semantic roadmap, providing a shared framework for both information specialists and users to navigate and interpret data consistently (Tudhope et al., 2006). The increasingly extensive use of Electronic Health Record (EHR) systems requires full semantic interoperability in order to achieve and pursue the objective of a comprehensive and reliable record of an individual's health history (Aminpour et al., 2014).

In Italy, the Fascicolo Sanitario Elettronico (FSE), which is the conceptual equivalent of the EHR, was enacted with the Legislative Decree No. 179/2012. It is based on a national federated and interoperable technological infrastructure, which supports patient's access to healthcare services throughout the country, by facilitating the exchange of clinical documents and data among healthcare providers and patients. Subsequently, the Prime Minister Decree No. 178/2015 regulated further aspects of the FSE, such as the data structure of some types of clinical documents. It then raised the question regarding the use of classification and coding systems to standardize and represent health and social-health data in the clinical documents of the FSE, in order to ensure, eventually recurring to transcoding, semantic interoperability at regional, national and international level. Specifically, the Technical Specifications attached to the Decree No. 178/2015 indicate the coding systems to be used within the FSE (Cardillo et al., 2016), including LOINC (Logical Observation Identifiers Names and Codes) for laboratory tests encoding into the Laboratory Report document type.

LOINC is a clinical terminology and the first universal pre-coordinated code system for laboratory test names, measurements, and observations (Forrey et al., 1996). LOINC has been developed by the Regenstrief Institute (RI) as an open standard and made available at no cost worldwide. In addition to the LOINC database, the RI also develops and distributes a mapping tool called the Regenstrief LOINC Mapping Assistant (RELMA). This tool facilitates research through the LOINC database and assists during the mapping operations between local tests and LOINC codes. Today LOINC is increasingly widespread all over the world, *de facto* becoming the reference standard for these medical concepts. It is currently used in more than 196 countries and translated into 15 languages and 20 linguistic variants (consult https://loinc.org/international/ for continuous updates on these numbers).

To address the local peculiarities of different countries, LOINC International has recognized a network of national partners around the world (Vreeman et al., 2012). As the LOINC purpose is to be integrated with local systems and not to substitute them, it was necessary to collaborate with local partners responsible for the translation of the standard and its implementation in their respective national contexts. Over time, central coordination has revealed essential for having a common reference point to address questions, support users, maintain relationships with governmental bodies and third parties, keep updated the standard and consider international updates and challenges in the domain. This role in Italy is played by the Institute of Informatics and Telematics of the National Research Council (IIT-CNR), which established the LOINC Italy working group, recognized as the official partner for Italy through a Memorandum of Understanding signed with the RI in 2014.

LOINC Italy's activities include biannual updates to the Italian translation of the LOINC database, translation of the LOINC Users' Guide into Italian, development of tutorials, provision of training courses, and mapping validation services. Additionally, an online helpdesk is offered on LOINC Italy website (www.loinc.it) for information requests and inquiries, along with the management of new LOINC codes submissions as needed.

This paper aims to present the approach chosen by the Friuli-Venezia Giulia Region for the implementation of LOINC codes into the electronic Laboratory Reports and, specifically, the mapping process underway in five large hospitals in the Region, highlighting the strengths and weaknesses of this experience and drawing lessons from it to systematize this practice.

2 LOINC MAPPING

Standardizing laboratory test requires using unique identifiers for each concept and clinical investigation to ensure consistent information exchange among laboratories. For effective semantic interoperability, each laboratory test needs to have a distinct representation of its specificities. Mapping local laboratory catalogues to LOINC deals with finding semantic equivalence of the clinical meaning of each test and assigning to it a unique code. The structure of each LOINC code is composed of six fundamental axes, which represent the pieces of information needed to detail the performed test with high level of granularity and specificity.

Nonetheless, mapping local terminologies to LOINC presents significant challenges, because local test names are idiosyncratic, often full of acronyms and abbreviations, and not always explicit with all the information necessary to uniquely identify the test.

This makes them understandable within the laboratory or hospital that created them but ambiguous outside them. The name alone is not sufficient to fully understand the examination performed, as information such as the execution method and the reporting unit of measurement are essential to distinguish its clinical meaning from others that may appear similar. At the same time, not everything labeled in a different way necessarily corresponds to substantively different tests. For example, the concept "level of glycosylated haemoglobin in blood" might appear as "HbA1C" in some systems, while others might refer to it as "Haemoglobin A1C" or "Glycohemoglobin" (Parcero et al., 2013). Therefore, making all the characteristics of a test explicit helps to quickly identify the correct LOINC code to map. Additionally, this reduce misinterpretations that can impact also the laboratory workflow, from the pre-analytical phase, through the analytical phase, to the post-analytical phase (Yusof & Arifin, 2016). Mapping local catalogues to LOINC helps to reduce these errors because of the need to remove ambiguity and provide a clear and consistent way to identify laboratory tests.

Implementing a robust LOINC mapping requires substantial planning, focused execution, and ongoing maintenance to keep it updated with the biannual releases of the standard. Even if it could not be easy to introduce in realities with already consolidated functioning, this standardization process is vital for enabling meaningful data exchange. By adopting a common reference terminology, hospitals can ensure that identical tests are recognized consistently, reducing errors and misinterpretations, and enhancing communication among healthcare providers.

After the entry into force of the aforementioned Prime Minister Decree No. 178/2015, there have been several regional initiatives and those of individual hospital structures that have chosen different approaches to the implementation of LOINC in Laboratory Reports, requesting or not the support of LOINC Italy. Even if this initiative aims to facilitate interoperability, improve patient care, and streamline data exchange among the laboratories, the lack of national coordination on the use of coding systems in clinical documents has caused fragmentation in the development and implementation of solutions that ensure efficient management of these systems.

The Friuli-Venezia Giulia Region decided to approach the mapping process starting from the laboratories of five large hospitals: CRO Aviano National Cancer Institute IRCCS of Aviano (PN), the Burlo children's hospital of Trieste, and the three-city hospital of Pordenone (ASFO), Udine (ASUFC) and Trieste (ASUGI). The work was coordinated by the in-house company, named Insiel, which manages all the health informatics process of the Region. The "mapping team" was composed by informaticians, MDs from CRO, and LOINC Italia experts. This has allowed different professionals gathered around the same table, who have contributed their expertise and their point of view to achieving a complex objective, in which the cooperation of IT, medical and specialist skills on the standard is essential to achieve an effective and efficient result. Preliminary meetings were held to analyze the situation and plan the work phases, as well as numerous meetings to monitor the progress of the activities.

Despite laboratories working with the same Laboratory Information System (LIS), they don't share the same tests catalogue. This means that laboratories could perform the same test but call it differently. Since carrying out a preliminary reconciliation of the local catalogues was deemed inconvenient for several reasons, the consequent decision was to map each hospital's catalogue to LOINC, although aware that this would have necessarily implied the duplication of mapping efforts on some tests. On the other hand, as a long-term objective, this approach would have allowed us to align hospitals' catalogues by reconciling multiple names for the same test and allowing to differentiate identical names that actually conceal clinically different tests in practice.

Considering the tests catalogues of the five mentioned hospitals, the total amount of tests to map to LOINC was 10,619. In accordance with Insiel, we decided to consider single tests only, and to postpone the panel's mapping. In LOINC a panel is a common name for groups of single tests that are usually ordered and/or reported together. In Italy it is also called *multiple* or *battery*. It could be more challenging because mapping a panel code means there must be matching in their respective child elements.

3 METHODS

The methodology defined for the mapping process involved several structured phases aimed at ensuring full semantic correspondence between local tests and LOINC codes and an effective validation process.

In January 2023, LOINC Italy experts delivered a comprehensive six-hour webinar to the MDs from the five involved laboratories, focusing on LOINC, RELMA and the mapping process. The education session was followed by a training session aimed to

familiarize laboratory staff with the LOINC coding system. After that, from February to June 2023, LOINC Italy experts provided dedicated mapping assistance on-site at each laboratory. This phase was crucial in facilitating hands-on support as laboratory MDs began to implement the mapping process. Throughout the training process, experts from LOINC Italy collaborated with laboratory teams to address any challenges and provide guidance tailored to their specific contexts and needs. The local laboratory catalogues were divided according to the different clinical specialties so the mapping could have been performed by the MD competent for the specific sector. This is a very important aspect, as local test catalogues contain a lot of implicit information, and sometimes even the information present is not always correct. This makes it clear that mapping is not purely an IT matter, as specific domain expertise is required. RELMA was used as a tool to support the mapping of local laboratory catalogues to LOINC.

Starting from July 2023, the laboratories have sent their locally mapped test catalogues to LOINC Italy, and the experts have started the third phase of the activity, which is the validation of the mappings. This phase includes a dual review process: at first, LOINC Italy experts verify the mappings based on the information in the local catalogues. When there are questionable mappings, they highlight the test in red and indicate the reason for not validating it. If there are tests that cannot be mapped because there is no LOINC code that represents them in a semantically equivalent way, they submit a request for the creation of a new LOINC code to LOINC International; subsequently, mapping MDs are involved for a direct discussion on questionable mapping cases in order to find together the right LOINC code or to model a new code submission. The involvement of clinical domain experts ensures that the terminology used aligns with medical practices and ensure that the test performed is correctly and semantically identified. On the other hand, LOINC Italy experts are responsible for verifying that there is conceptual correspondence between source and target codes and that the modelling of requests for new codes should be done according to the formalisms of the standard.

Once the mappings have been validated, it was then possible to compare them through the chosen LOINC code to detect any inconsistencies.

At the conclusion of this experience, it was considered essential to gather feedback from the clinical users involved in the mapping process. To this end, one of the participating physicians was asked to evaluate the experience with the RELMA software and to provide his insights into the application of the LOINC standard. This included identifying any challenges encountered, suggesting areas for improvement, and highlighting potential benefits. Additionally, the physician was invited to offer his perspective as a clinical expert on the representativeness of LOINC codes across different laboratory specialties, as well as his thoughts on potential future applications of the standard and how the results achieved in this work could be expanded and reused.

4 RESULTS

The total amount of tests mapped to LOINC is 10,619: 1,013 are from CRO; 2,615 are from ASFO; 3,670 are from ASUFC; 1,693 are from ASUGI, and 1,628 are from Burlo children hospital. The first three have already completed mapping the tests from their local catalogues to LOINC, while for the remaining two, the work is still in progress. Below the results of the mappings realized by CRO, ASFO, and ASUFC are presented, in particular describing percentages of correct mappings, submissions to LOINC for requesting new codes, and tests identified as non-mappable because they are either obsolete or only used for internal calculations and therefore not reportable into the Laboratory Reports.

CRO mapped 1,013 test codes, belonging to clinical pathology, clinical biochemistry and clinical and experimental oncohematology. The mapping was performed by 1 MD, who collected the necessary information from his colleagues. For 865 of the tests, it was possible to identify an existing LOINC code, even after several clarification meetings between LOINC Italia experts and the MD. The tests for which it was not possible to identify an existing LOINC code amounted to 94. LOINC Italy started the submission process to request the creation of new LOINC codes to semantically represent them. This process has a median processing time of approximately 45 days. The created terms are then published in the subsequent LOINC release; however, once developed, they can be viewed on the pre-release term webpage (https://loinc.org/prerelease/). Furthermore, the mapping process enabled the MD to identify inconsistencies in the catalogue, consisting of 5 tests non-mappable because they are either not representative of unique results or used for internal calculations that do not generate reportable outcomes, and 54 tests that are no longer performed. So mapping was also the chance to clean up the local catalogue. Figure 1 shows the percentage distribution of

mappings completed by CRO across the described categories.

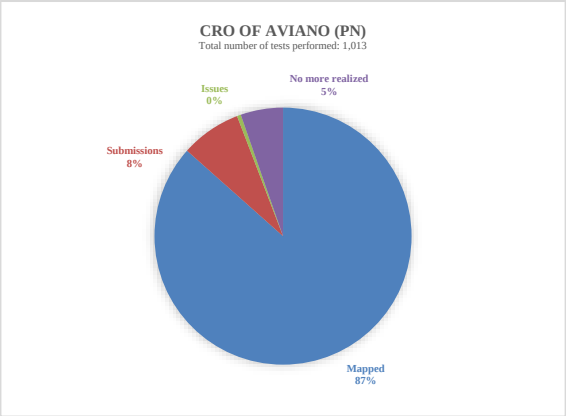

Figure 1: The percentage distribution of mappings completed by CRO according to the described categories.

In the ASFO hospital the mapping process covered a total of 2,615 test codes. The local catalogue was divided among 4 MDs, according to the laboratory specialties of their specific expertise. The tests belong to the following sectors: allergy, autoimmunity, bacteriology, biochemistry, hematology, endocrinology, gastroenterology, HLA, injury markers, nephrology, POCT, serology, toxicology, and virology. Overall, the tests mapped to a LOINC code amount to 2,113; those for which a submission process has been initiated to request the creation of a specific LOINC code are 228; 3 have been classified as non-mappable for the same reasons stated for the CRO; while 43 refers to tests no longer performed. Figure 2 shows the percentage distribution of mappings completed by ASFO across the categories described.

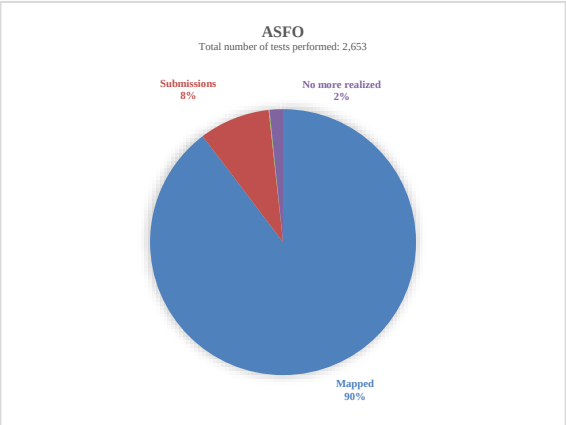

Figure 2: The percentage distribution of mappings completed by ASFO according to the described categories.

ASUFC mapped a total of 3,670 codes from multiple laboratory sectors, such as allergy, chemistry, autoimmunity, molecular biology, coagulation, electrophoresis, hematology, toxicology, gastroenterology, inhibition, cerebrospinal fluid, cardiac markers, injury markers, microbiology, hormones, POCT, urine, uroporphyrins, and virology. The mapping was performed by 2 MDs, who gathered necessary information from other laboratory specialties' MDs. Of them, 3,347 tests were mapped to an existing LOINC code; 283 were formally modeled to request a new LOINC code; 9 are non-mappable codes and 31 no longer realized. Figure 3 shows the percentage distribution of mappings completed by ASUFC across the categories described.

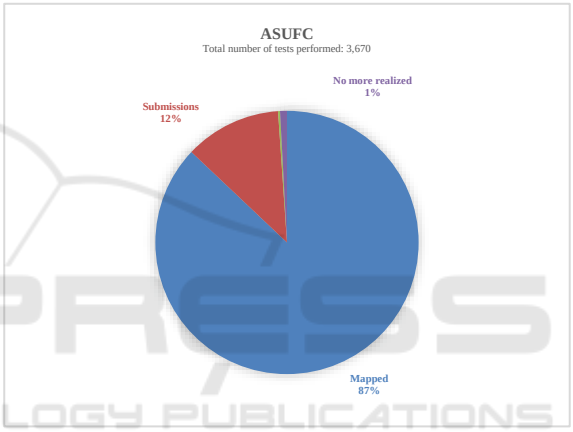

Figure 3: The percentage distribution of mappings completed by ASUFC according to the described categories.

4.1 Mapping Peculiarities

In this paragraph, we would like to present some peculiarities observed during the validation of mappings. First and foremost, it is important to specify that the effort required to verify the correctness of the semantic association between the source code and the target code is not uniform across all laboratory specialties. There are, in fact, highly structured and consolidated sectors, either because they consist of common and recently defined tests, such as clinical chemistry, or because they are internally standardized, such as allergology. On the other hand, there are specialties characterized by continuous and rapid evolution, where new tests are frequently formalized, such as genetics, as well as sectors with recognized intrinsic complexity, such as microbiology.

In Allergology, the use of Allergen International Codes as synonyms for the Latin name of the allergen reported in the LOINC component helps quickly identify the correct code to map. Nonetheless, even if international codes are used to identify allergens, it was necessary to pay close attention to the test description. For example, the sole label "sunflower" in the tests “w204 sunflower serum” and “k84 sunflower serum” is not sufficient to distinguish between tests on pollen or seeds. However, thanks to the presence of the international codes w204 and k84, it was possible to assign the correct LOINC code to each test. Always verifying the correct semantic interpretation of the test remains crucial to identifying the most accurate LOINC code. For instance, in the case of the local test “t45 North American elm serum” the international code was misleading because it corresponds to another species of elm, namely *Ulmus Crassifolia*. In this case, it was necessary to consult the competent physician to clarify whether the international code or the allergen name had been incorrectly indicated.

In multiple cases we found idiosyncratic local test names to describe substantially the same test. For example, the LOINC code 1756-6 *Albumin in CSF/Albumin in Serum or Plasma* was assigned to both the tests named “Barrier Permeability of CSF” and “Albumin Quotient of CSF”. This is actually the reason why going to international standards such as LOINC is so crucial, and it shows how the correct interpretation of the test semantics is the only way to identify the most accurate LOINC code. In other cases, the level of granularity required by LOINC in the test description, compared to the lack of descriptive detail in local test catalogues, makes the mapping validation difficult, as much of the information is implicit. This often leads also the physician to map to a more general LOINC code, even though a more specific one would exist. Representativeness and granularity issues emerged mainly for the System axis of virology and bacteriology tests. For example, the tendency is to use LOINC codes with System *Respiratory system specimen.lower* even if specifying it in *Bronchial* or *BAL* would be possible. In the case of the ASFO hospital, 41 new LOINC codes with *BAL* in the System axis were requested. It was necessary to ensure an accurate representation of the test performed. The guiding principle is to always request new codes if they need to disambiguate and uniquely identify a test with a greater level of detail.

4.2 New LOINC Codes Submissions

The validation of the mappings realized by the five hospitals inevitably required requesting the LOINC Committee to create new LOINC codes for concepts that were not represented by the existing ones. These are not always tests recently introduced in the scientific reference domain; sometimes, they are requests to narrow the scope of an existing code, while other times, they are tests specific to a context different from the North American operational setting. New LOINC code submissions require a thorough understanding of the standard's formalism, as the local test must be "translated" into the six fundamental LOINC axes, potentially providing supporting documentation necessary to better understand what is effectively tested. For this reason, the submission process is always carried out by LOINC Italy.

The chart in Figure 4 shows the distribution of submissions across the CRO, ASFO, and ASUFC hospitals, for a total of 605 submissions, specifying those that have already led to the creation of new LOINC codes (194 out of 605) and those that are still under review of the LOINC content developers (411 out of 605). The process of creating a new LOINC code does not stop at the submission, as interactions with LOINC content developers are often necessary to precisely identify the clinical meaning of the test and the semantics to be conveyed through the six LOINC axes.

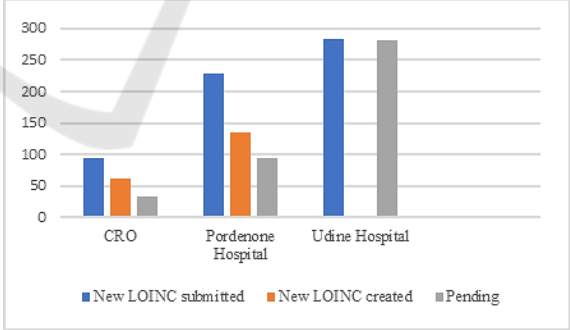

Figure 4: New LOINC codes submissions in the CRO, ASFO and ASUFC hospitals.

Regarding the laboratory specialties for which the highest number of new codes have been requested, also considering the observations presented in the previous paragraph, it is not surprising that the highest number of new LOINC codes submissions came from virology and bacteriology, respectively with 83 and 137 submissions.

4.3 User Experience

Since we believe that user experience is not a marginal aspect in the implementation of the LOINC standard, we asked one of the doctors who actively participated in the mappings to share his impressions regarding this activity. He started considering the challenges posed by the complex and often non-intuitive structure of the LOINC lexicon but recognizing that before engaging in any meaningful mapping task, it is firstly necessary that users familiarize themselves with the six fundamental LOINC axes, which serve as the foundation for understanding the LOINC coding structure. Without this knowledge, navigating the code system becomes significantly more difficult, making the mapping process less effective and efficient. About RELMA he highlights that it has its own complexity because of its relatively unfamiliar user interface, although acknowledging that uploading local databases, mapping, and exporting results is relatively straightforward. Challenges lie in mastering the technical language, understanding the user interface, and filtering algorithms used by the software.

According to his mapping experience, finding the semantically correspondent LOINC code depends heavily on the precision of the search queries. If user does not get any result, criteria used to filter results in the "search limits" should be considered as they can drastically alter the outcomes. This highlights the importance of a deeper understanding of search algorithms, a skill set not typically possessed by medical professionals. As a result, non-technical users may struggle to achieve the most accurate mappings without additional training or support. The high level of granularity in the description of tests often multiplies the descriptive strings, and therefore, even when the user performs a search using a single term and expects a direct result, he/she has to deal with multiple strings. In these cases, users have to consider factors such as the ranking of results or the number of institutions that have chosen a particular code, opting for what appears to be the most commonly accepted option. This, however, does not eliminate the need for LOINC expert validation, particularly in areas where there is a high degree of ambiguity. Furthermore, users operating in unfamiliar domains are often required to consult with domain experts. This adds both time and complexity to the task, increasing the potential for human error.

However, he is keen to point out that there are not only negative aspects and that in fact once users have mastered these technical aspects, the mapping process tends to progress smoothly and efficiently. As familiarity with the LOINC terminology and the RELMA software grows, the system reveals its strengths, particularly in its ability to filter results effectively based on well-constructed queries. Additionally, the use of standard units of measurement significantly aids in narrowing down the search results, ensuring greater and faster accuracy in the mapping process. This functionality proves particularly valuable in more established domains, where consistency in test specifications allows for quicker and more reliable mappings.

About representativeness, he noticed that LOINC offers a robust and well-structured framework for mature fields such as clinical chemistry, while newer areas like molecular diagnostics are not yet as well-represented. In these fields, LOINC codes may be missing or lack the granularity required for detailed mapping, indicating that the code system has not fully caught up with advancements in these scientific areas yet.

In conclusion, he thinks that LOINC holds considerable promises for facilitating cross-national interpretation of laboratory results, especially as the number of mapped local catalogues increases. In the recently launched European Health Data Space LOINC could be instrumental in harmonizing inter-laboratory data across borders, enhancing the interoperability of health data. Moreover, LOINC codes can contribute to the development of artificial intelligence (AI) and machine learning models by providing a standardized framework for similar tests, thus bypassing the need for manual annotation and transcoding. This still relies on the availability of tests correctly mapped to LOINC through human effort or at least validated by a human expert. However, the main critical challenge he foresees might stem from the lack of specificity regarding the method, as it is the only axis with optional specification. This, in fact, could make tests based on different methodologies appear equivalent. This could introduce significant variability, potentially skewing AI models.

5 DISCUSSIONS

Programming and implementing the mapping of laboratory tests from three hospitals in the Friuli Venezia Giulia region to the LOINC standard codes enabled the analyses described in the previous paragraph but also allowed for some reflections on the mapping work in general. The mapping of local laboratory catalogues to LOINC is an onerous but essential process for achieving standardization. Despite its complexity, efficient planning and

programming can significantly reduce the workload, ensuring that resources are utilized effectively. It is crucial to place the right competencies in the right place at the right time, relying on both domain experts and LOINC specialists to ensure accurate mappings.

Anticipating the most frequently asked question from doctors, we always recommend paying attention to “false friend mappings”, that is the risk of relying on mappings performed by other laboratories without carefully reviewing all the descriptive parameters of the tests before fully adopting their mappings. Tests that may appear similar in name can differ in context or clinical specificity and should therefore be mapped differently. Conversely, not everything labeled differently necessarily represents fundamentally different tests. Explicitly stating the values corresponding to the six fundamental LOINC axes is the only way to uniquely identify a test.

As a result of what has been explained so far emerges that it is not feasible to adopt a systematic method for mapping the local catalogues of different hospitals to LOINC. A deep understanding of the information being represented at a semantic level is essential and, even when two tests appear similar, careful consideration is needed to distinguish between them. Additionally, it is not only the naming of the tests that matters, but also the way the results are reported. This includes whether the findings are presented as a laboratory report in natural language or as evidence based on a specific scale. The way the tests are documented significantly influences the choice of the correct LOINC code. Therefore, it is not possible to apply a uniform method across all hospitals, as factors such as the form of reporting and the specific context of each test must be taken into account when selecting the appropriate LOINC code.

Additionally, if the search for a LOINC code to map does not yield any results, one should not immediately resort to requesting the creation of a new code through submission, especially when dealing with well-known tests. Often, the appropriate LOINC code already exists and simply needs careful identification, for example trying to search with synonyms or to better focus on the core of the analyte.

Finally, conducting a reverse check of the mappings at the end of the work is essential. This step helps in identifying potential errors, such as incorrect mappings, overlaps between local codes, and duplications. By implementing this review, the overall accuracy and consistency of the mapping are greatly improved. The Friuli Venezia Giulia’s in-house company was thus able to achieve a general reorganization of the catalogues of the hospitals involved, ensuring consistency, particularly in the two (CRO and ASFO) that share the same test catalogue. Additionally, it was possible to identify codes that appeared to represent single tests but produced in the Laboratory report a series of results corresponding to multiple observable values, thus effectively functioning as panel codes.

Finally, it was possible to draft a sort of ranking of mapping based on difficulty, identifying the specialties from which it would be advisable to start, as they are simpler, e.g. allergology because of the use of Allergen international codes to quickly identify the right LOINC component to map to; clinical chemistry is also among the sectors that can be easily mapped, as the tests have been consolidated for a long time and are well-structured in the values of the six fundamental LOINC axes.

6 CONCLUSION AND FUTURE WORK

This paper describes the approach chosen by the Friuli Venezia Giulia Region in Italy to map laboratory catalogues of five big hospitals to LOINC. The mapping was manually performed by medical doctors using RELMA. Overall, over 7,000 local tests have been mapped to LOINC and the creation of 675 new LOINC codes was requested to represent concepts not included in the standard. Of these, 194 have already been created and are part of the official LOINC releases. Thus, a sort of regional LOINC knowledge base has been created.

Mapping local terms to a standardized vocabulary is not only a matter of interoperable informative systems, but it requires a deep knowledge of both the source and target terminology structures, i.e. the organization of tests in the local catalogue, which usually reflects not only a scientific criterion but also a functional one, and the structuring of a coding standard such as LOINC. It is a demanding task the first time, but it becomes easy to maintain afterward, and the advantages it offers in terms of data traceability and semantic interoperability are countless. In our work, it was necessary to find solutions to the multiple issues encountered during the mapping and it was possible to address them through a continuous collaboration among the clinical staff, the LOINC experts and the informaticians involved in the activity. The high percentages of correct mappings and the low percentages of not identified matches demonstrate that training activities and mapping support play a fundamental role in understanding the right way to approach this

standard. An integrated management of a medical terminology cannot be able to leave all those aspects out of consideration, as they all contribute to make effective and efficient the use of a standardized system.

All the experiences and specific cases encountered so far will serve in the future as a valuable knowledge base for improvements and efficiencies of the mapping process, potentially streamlining and accelerating the mapping process itself and enabling work in an AI-driven environment.

Future work prospects include the need to complete the validation of mappings carried out by the two remaining hospitals out of the five (ASUGI and Burlo Children's Hospital), covering a total of 3,321 local tests; finalize all pending submissions of new LOINC terms; and, most importantly, in collaboration with all stakeholders define maintenance policy for the mappings performed and establish procedures for mapping new tests that will be introduced in the catalogues of the five hospitals involved.

REFERENCES

Aminpour, F., Sadoughi, F., & Ahamdi, M. (2014). Utilization of open source electronic health record around the world: A systematic review. *Journal of Research in Medical Sciences: The Official Journal of Isfahan University of Medical Sciences*, *19*(1), 57–64.

Cardillo, E., Chiaravalloti, M. T., & Pasceri, E. (2016). Healthcare Terminology Management and Integration in Italy: Where we are and What we need for Semantic Interoperability. *European Journal for Biomedical Informatics*, *12*(01). https://doi.org/10.24105/ejbi.2016.12.1.14

European Commission: Directorate-General for the Information Society and Media. (2009). *Semantic interoperability for better health and safer healthcare: Deployment and research roadmap for Europe*. Publications Office of the European Union. https://data.europa.eu/doi/10.2759/38514

Forrey, A. W., McDonald, C. J., DeMoor, G., Huff, S. M., Leavelle, D., Leland, D., Fiers, T., Charles, L., Griffin, B., Stalling, F., Tullis, A., Hutchins, K., & Baenziger, J. (1996). Logical observation identifier names and codes (LOINC) database: A public use set of codes and names for electronic reporting of clinical laboratory test results. *Clinical Chemistry*, *42*(1), 81–90. https://doi.org/10.1093/clinchem/42.1.81

Gotlieb, R., Praska, C., Hendrickson, M. A., Marmet, J., Charpentier, V., Hause, E., Allen, K. A., Lunos, S., & Pitt, M. B. (2022). Accuracy in Patient Understanding of Common Medical Phrases. *JAMA Network Open*, *5*(11). https://doi.org/10.1001/jamanetworkopen.2022.42972

Iroju, O., Soriyan, A., Gambo, I., & Olaleke, J. (2013). *Interoperability in Healthcare: Benefits, Challenges and Resolutions*. *3*(1).

Parcero, E., Maldonado, J. A., Marco, L., Robles, M., Bérez, V., Más, T., & Rodríguez, M. (2013). Automatic Mapping tool of local laboratory terminologies to LOINC. *Proceedings of the 26th IEEE International Symposium on Computer-Based Medical Systems*, 409–412. https://doi.org/10.1109/CBMS.2013.6627828

Tudhope, D., Koch, T., & Heery, R. (2006). *Terminology Services and Technology*.

Vreeman, D. J., Chiaravalloti, M. T., Hook, J., & McDonald, C. J. (2012). Enabling international adoption of LOINC through translation. *Journal of Biomedical Informatics*, *45*(4), 667–673. https://doi.org/10.1016/j.jbi.2012.01.005

Yusof, M. M., & Arifin, A. (2016). Towards an evaluation framework for Laboratory Information Systems. *Journal of Infection and Public Health*, *9*(6), 766–773. https://doi.org/10.1016/j.jiph.2016.08.014