ICIPEMIR: Improving the Completeness, Interoperability and Patient Explanations of Medical Imaging Reports

Arthur LAURIOT DIT PREVOST^{a, b,1} Marie TRENCART^{a,b}, Vianney GAILLARD^c, Guillaume BOUZILLE^d, Rémi BESSON^{a, b}, Dyuti SHARMA^{a, b}, Philippe PUECH^c, and Emmanuel CHAZARD^a

^aUniv. Lille, CHU Lille, ULR 2694 METRICS, F-59000 Lille, France ^bCHU Lille, Clinique de Chirurgie et Orthopédie de l'Enfant, F-59000 Lille, France ^cUniv. Lille, Inserm, CHU Lille, U1189 - ONCO-THAI, F-59000 Lille, France ^dUniv Rennes, CHU Rennes, Inserm, LTSI - UMR 1099, F-35000 Rennes, France

> Abstract. Introduction. Although electronic health records have been facilitating the management of medical information, there is still room for improvement in daily production of medical report. Possible areas for improvement would be: to improve reports quality (by increasing exhaustivity), to improve patients' understanding (by mean of a graphical display), to save physicians' time (by helping reports writing), and to improve sharing and storage (by enhancing interoperability). We set up the ICIPEMIR project (Improving the completeness, interoperability and patients explanation of medical imaging reports) as an academic solution to optimize medical imaging reports production. Such a project requires two layers: one engineering layer to build the automation process, and a second medical layer to determine domain-specific data models for each type of report. We describe here the medical layer of this project. *Methods*. We designed a reproducible methodology to identify -for a given medical imaging exam- mandatory fields, and describe a corresponding simple data model using validated formats. The mandatory fields had to meet legal requirements, domain-specific guidelines, and results of a bibliographic review on clinical studies. An UML representation, a JSON Schema, and a YAML instance dataset were defined. Based on this data model a form was created using Goupile, an open source eCRF script-based editor. In addition, a graphical display was designed and mapped with the data model, as well as a text template to automatically produce a free-text report. Finally, the YAML instance was encoded in a QR-Code to allow offline paper-based transmission of structured data. Results. We tested this methodology in a specific domain: computed tomography for urolithiasis. We successfully extracted 73 fields, and transformed them into a simple data model, with mapping to a simple graphical display, and textual report template. The offline QR-code transmission of a 2,615 characters YAML file was successful with simple smartphone QR-Code scanner. Conclusion. Although automated production of medical report requires domain-specific data model and mapping, these can be defined using a reproducible methodology. Hopefully this proof of concept will lead to a computer solution to optimize medical imaging reports, driven by academic research.

Keywords. Data model, medical imaging report, QR-Code, patient participation.

¹ Corresponding Author, Arthur LAURIOT DIT PREVOST, Clinique de Chirurgie et Orthopédie de l'Enfant, CHU Lille - Hôpital Jeanne de Flandre, Avenue Eugène Avinée, F-59000 Lille;E-mail: arthur.lauriotditprevost@chru-lille.fr.

1. Introduction

Free text medical reports are the standard support for medical information. Medical imaging reports are the primary interface between the radiologist, the patient, and the prescribing physician. Improving radiological reporting practice is a growing area of interest in the medical literature, especially report's quality, format, language, length, content and completeness, turnaround time, and mode of result delivery to patients [1,2]. Medical information also plays a central role in physician-patient relationship, especially with the concept of patient empowerment [3]. Improving the patients' understanding of their conditions, results in a higher adherence to care [4]. This could be achieved using graphical display [5].

For that purpose, we initiated the ICIPEMIR project: "Improving the completeness, interoperability and patients' explanation of medical imaging reports". The objective is to design a workflow for producing domain-specific medical imaging reports based on upstream production of structured data by the radiologist and automated production of both textual report and schematic graphical representation. Expected benefits would be: improved completeness and clarity through synoptic reporting [6], higher patient understanding through schematic graphical representation of the result, faster report writing, and enhanced storage and sharing of structured data for future clinical research. Interoperability is also a crucial point when dealing with health data [7]. Although efforts were made towards interoperability Resources) [8] or OpenEHR [9], these standards remains complex structures. Besides, as the traditional decentralized paper-based transmission has proven effective and safe for transmitting and storage of unstructured data through this communication channel, with the use of QR-Codes.

Figure 1 presents the intended final use of ICIPEMIR products. The radiologist would fill-in a domain-specific form with pre-defined fields, to generate a printed imaging report composed of: (1) a standard text report, (2) a graphical display, and (3) a QR-Code embedding the structured data.

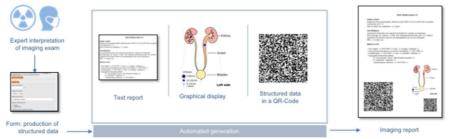


Figure 1. ICIPEMIR workflow for automated production of imaging report.

The QR-code would enable to safely store on the paper and transmit offline medical information. The QR-Code would embed any URL, but a small data file, to enable data sharing without security issue: as the patient is allowed to carry and transmit the paper report, he is also allowed to carry and transmit the encoded data. This first requires defining mandatory information, in the form of a specific data model, which can only be done for a given imaging exam, and a given indication. The objective of this paper is to describe our methodology to define the required information and structure them as a simple data model for computed tomography for urolithiasis.

2. Method

2.1. Field definition: literature-based definition of relevant fields with expert validation

We conducted a narrative bibliographic review using the Medline database (on http://pubmed.gov), Google, and Google Scholar, to identify guidelines on medical imaging reporting in general, and more specifically related to targeted exam and indication (here computed tomography for urolithiasis). We also included legal requirement on medical reporting, by screening the French official health agency and health regulation codes. We also searched the Medline database for scientific papers reporting imaging results of patients suffering from urolithiasis. The objective was to identify the pieces of information the authors had found relevant to report.

The list of items to report was blindly reviewed by 4 independent experts from our university hospital (a radiologist, a general practitioner, a urologist, and a medical informatics specialist). A final consensus meeting was organized.

2.2. Data model: standardization of the data collection within the report

The list of fields was transformed into a simple data model (Figure 2) and modelized using UML [10]. We then defined a possible instance of the data model using the YAML syntax [11]. We also defined the corresponding JSON schema [12] for schema validation. Finally, we used the web-based open source e-CRF tool Goupile [13], to output a shareable easy-to-use form for any imaging report in the defined domain. The form was intended to output the data following the YAML syntax defined above. The YAML file was finally encoded into an automatically generated QR Code with a 7% error. This format enables to embed up to 2,953 characters.

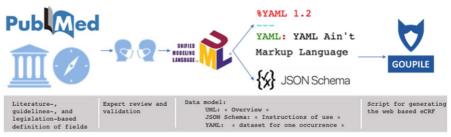


Figure 2. Iterative methodology for domain-specific data model definition.

3. Results

We tested this methodology on computed tomography for urolithiasis. The final model retained 73 fields (**Figure 3**), divided into 3 tables with different cardinality, that was handled by JSON and YAML syntax (e.g. the variable size of the lithiasis was likely to appear more than once in a single report, so we created a table for lithiasis related fields). A JavaScript file was also written to produce a form from Goupile. All result files can be found online on https://github.com/arthurldp/medical_imaging_report. The QR-Code containing a 2,615 character YAML file was successfully decoded by 4 out of 5 smartphone models, of which one model retrieved the data through the native camera application, and 3 through different non-native QR Code scanning apps.

r : string tient_first_name : string tient_first_name : string tient_brith : date stiution : string addetLime : date addetLime : date addetLime : date addetLime : date addetLime : date addetLime : date addition : categorical dition_contrast : categorical dition_contrast : categorical dition_scute : categorical dition_scute : categorical dition_ferver : categorical dition_ferver : categorical normal_drenals : categorical normal_drenals : categorical normal_uphenes : categorical normal_wories : categorical normal_uphenes : categorical diversion : categorical renal_uphenes : categorical diversion : categorical diversion : categorical renal_uphenes : categorical diversion : categorical renal_uphenes : categorical renal_uphenes : categorical diversion : categorical renal_uphenes : cat	0*
<pre>tient_first_name : string tient_first_name : string tient_name : string tient_name : string tient_name : string stitution : string an_datetime : date an_type : categorical vice_model : string vice_date : date an_indication : categorical ndition_contrast : categorical ndition_fervart : categorical ndition_fervart : categorical ndition_radiation : real normal_vances : categorical filtration_gapedix : categorical normal_vances : categorical filtration_gapedix : categorical filtration_gapedix : categorical normal_vances : categorical normal_vances : categorical filtration_signid : categorical na_transplant : categorical na_transplant : categorical nal_transplant : categorical ndifus : integer ndings : categorical rther_imaging : categorical ntrol_imaging_delay : string </pre>	hiasisResults
<pre>tient_name : string tient_name : string tient_hith : date ysician : string an_datetime : date an_indication : string an_datetime : date an_indication : categorical andition_contrast : categorical andition_contrast : categorical andition_contrast : categorical andition_contrast : categorical andition_scute : categorical andition_scute : categorical andition_scute : categorical andition_rever : categorical andition_rever : categorical anormal_adrenals : categorical anormal_waries : categorical anormal_puphnode : categorical anormal_puphnode : categorical ana_trapplant : categorical ana_trupe : string ating : categorical anding : categorical anding : categorical ana_trapplysician : actegorical ana_trapplysician : actegorical ana_trapplys</pre>	: hash (
<pre>ysician : string stitution : string stitution : string addetime : date am_intype : categorical mition_contrast : categorical ndition_contrast : categorical ndition_contrast : categorical ndition_scute : categorical ndition_scute : categorical ndition_scute : categorical ndition_radiation : real normal_varies : categorical normal_upences : categorical normal_pancreas : categorical normal_varies : categorical filtration_apendix : categorical normal_varies : categorical filtration_apendix : categorical filtration_apendix : categorical filtration_apendix : categorical filtration_apendix : categorical filtration_signid : categorical inal_trapsplant : categorical inal_trapsplant : categorical rther_imaging : categorical rther imaging : categorical r</pre>	: catego
<pre>ysician : string stitution : string atitution : string stitution : string wice_date : date am_type : categorical wice_model : string wice_date : date am_indication : categorical ndition_contrast : categorical ndition_ferver : categorical ndition_derivation : categorical normal_ver : categorical normal_penches : categorical filtration_agendax : categorical filtration_signid : categorical itmapritoneum : categorical def_lithiasis : integer nal_transplant : categorical withiasis : integer ndings : categorical rther_imaging : categorical rther_imaging : categorical ntrol_imaging_dely : string hematuria hematuria ntrol_imaging_dely : string</pre>	: catego
<pre>stitution : string an_datetime : date an_datetime : date an_datetime : categorical an_datetime : date an_indication : categorical ndition_contrast : categorical ndition_soute : categorical ndition_soute : categorical ndition_derivation : categorical ndition_radiation : real normal_parcreas : categorical normal_parcreas : categori</pre>	
am_antrime i date i date i date i density uvj.distance i date i d	: catego
<pre>vice_model : string vice_model : string wice_date : date an_indication : categorical ndition_contrast : categorical ndition_contrast : categorical ndition_fever : categorical ndition_fever : categorical normal_vizent : categorical filtration_signoid : categorical nal_transplant : categorical nal_transplant : categorical nal_transplant : categorical nal_transplant : categorical ndifies : integer ndings : categorical rther_imaging : categorical rther_imaging : categorical rther_imaging : categorical ntrol_imaging : categorical rther_imaging : categorical rther imaging : categorica</pre>	: catego
<pre>vice_date : date</pre>	: real
<pre>vice_date : date</pre>	: real
<pre>am_indication : categorical infilteration dition_contrast : categorical dition_acute : categorical dition_derivation : categorical dition_derivation : categorical normal_adrenals : categorical normal_spleen : categorical normal_spleen : categorical normal_spleen : categorical normal_spleen : categorical diftration_gallbladder : categorical filtration_gandbladder : categorical filtration_gandbladder : categorical diversion : categorical intrajension : categorical itthasis : integer dider_lithasis : categorical rther_hysician : categorical trither_imaging : categorical trither_imaging : categorical trither_diversion : categorical trither_diversion : categorical trither_hysician : categorical trither_diversion : ca</pre>	: real
<pre>nallon_contrast : categorical ndition_twose : categorical ndition_scute : categorical ndition_scute : categorical ndition_fervistion : categorical normal_varies : categorical filtration_apendix : categorical filtration_apendix : categorical filtration_sigmoid : categorical rtaperitoneum : categorical nal_trapslant : categorical nal_trapslant : categorical nal_trapslication : categorical rtaperitoneum : categorical rther_bhylication : categorical rther_imaging : categorical rther_imaging : categorical rther_imaging : categorical rther_physician : categorical rther_physician : categorical rther_physician : categorical rther_imaging : categorical rther_physician : categorical rther_imaging : categorical rther physician : categorical</pre>	
ndition_scute : categorical nephrography ddition_fever : categorical nephrography formix_rupture comment normal_liver : categorical normal_pancreas : categorical normal_pancreas : categorical normal_penet : categorical normal_pupphote : categorical normal_pupphote : categorical filtration_sgnedix : categorical filtration_sgnedix : categorical diversion renal_height : categorical diversion diversion diversion diversion renal_height : categorical traperizoneal_effusion : categorical lithiasis : integer ndings : categorical rther_imaging : categorical rther_imaging : categorical rther_imaging : categorical rther_imaging : categorical rther_imaging : categorical rther_imaging : categorical rther_physician : categorical rther_imaging : categorical rther_imaging : categorical rther_imaging : categorical rther_imaging : categorical rther_physician : categorical rther_imaging : categorical rther imaging	: catego
ndition_fever : categorical memory of formix_rupture ndition_derivation : categorical formix_rupture normal_liver : categorical comment normal_adremals : categorical comment normal_gatemals : categorical comment normal_spleen : categorical comment filtration_appendix : categorical catego	: catego
<pre>ndition_fever : categorical ndition_traviation : categorical normal_dramals : categorical normal_apancreas : categorical normal_ymphnode : categorical normal_ymphnode : categorical normal_ymphnode : categorical filtration_appendix : categorical filtration_appendix : categorical filtration_appendix : categorical filtration_signoid : categorical mal_transplant : categorical mal_transplant : categorical lithiasis : integer ndings : categorical filtration_signoid : categorical filtration : string filtration_signoid : categorical filtration : string filtration_signoid : categorical filtration : string filtration : str</pre>	: catego
<pre>ndition_adiation : categorical normal_liver : categorical normal_adrenals : categorical normal_adrenals : categorical normal_spleen : categorical normal_spleen : categorical normal_with the spleen : categorical filtration_aplubladder : categorical filtration_aplubladder : categorical filtration_aplubladder : categorical inary_tract_doplication : categorical inary_tract_doplication : categorical inary_tract_doplication : categorical intrageritoneal_effusion : categorical dider_lithiasis : integer ndings : categorical wither_imaging to categorical remal_parenchy interlabial_pe urteral_diame urteral_diame urteral_diame urteral_diame probability : categorical urteral_diame urter</pre>	
<pre>marticle data in the set of the set of</pre>	
normal_adrenals : categorical normal_pancreas : categorical normal_spleen : categorical normal_spleen : categorical normal_vymphnode : categorical filtration_appendix : categorical filtration_spmoid : categorical eumoperitoneum : categorical eumoperitoneum : categorical inary_tract_duplication : categorical nal_transplant : categorical inder_lithiasis : categorical itvic_phlebolith : categorical etter_inaging : categorical rther_inaging : categorical rther_inaging : categorical rther_inaging : categorical rther_inaging : categorical rther_inaging : categorical rther_physician : categorical rther_physician : categorical rther_physician : categorical rther_inaging : categorical rther_inaging : categorical rther_inaging : categorical rther_physician : categorical rther_inaging :	: string
normal_pancreas : categorical normal_opancreas : categorical normal_ovaries : categorical normal_lymphnode : categorical filtration_gallbladder : categorical filtration_sigmoid : categorical filtration_sigmoid : categorical tinary_tract_duplication : categorical inary_tract_duplication : categorical inary_tract_duplication : categorical diversion mal_transplant : categorical diversion renal_height renal_pancndy inter_libhiasis : integer difficult : categorical inter_imaging : categorical urther_imaging : categorical urther_imaging : categorical urther_imaging : categorical trther_imaging : categorical urther_physician : categorical urther_physician : categorical trther_imaging : categorical trther_imaging : categorical trther_imaging : categorical trther_physician : categorical trther_imaging : categorical trther_physician : categorical trther_imaging : categorical	
normal_spleen : categorical normal_wphode : categorical filtratio_gallbladder : categorical filtratio_gapendix : categorical filtratio_spendix : categorical eumoperitoneum : categorical traperitoneal_effusion : categorical mary_tract_duplication : categorical adder_lithiasis : categorical diversion renal_kheinht renal_volume renal_volume renal_volume renal_contour_i interlabial_pe lithiasis : integer different different rther_imaging : categorical rther_imaging : categorical rther_imaging : categorical rther_bysician : categorical : categorical rther_bysician : categorical : categorical :	
normal_ovaries : categorical normal_lymphnode : categorical filtration_appendix : categorical filtration_sigmoid : categorical eumoperitoneum : categorical traperizoneal_effusion : categorical mal_transplant : categorical nal_transplant : categorical mal_transplant : categorical lithiasis : categorical lithiasis : integer ndings : categorical trther_imaging type : string ntrol_imaging,delay : string ntrol_imaging,delay : string	
normallymphnode : categorical filtration_gallbladder : categorical filtration_gallbladder : categorical filtration_sigmoid : categorical filtration_sigmoid : categorical tinary_tract_duplication : categorical inary_tract_duplication : categorical inary_tract_duplication : categorical inter_insplant : categorical adder_libthasis : categorical lithiasis : integer ndings : categorical ureteral_dimer trber_immging : categorical ureteral_dimer ureteral_dimer trber_immging : categorical ureteral_dimer uretera	
filtration_gallbladder : categorical urinary_tract_ filtration_appendix : categorical diversion traperitoneum : categorical diversion traperitoneum : categorical real_height inary_tract_doplication : categorical nal_transplant : categorical real_out lvic_phlebolith : categorical def_litibasis : categorical def_lithasis : categorical itthesis : integer extrasingag : categorical ureteral_diame trther_imaging : categorical ureteral_diame trther_physician : categorical ureteral_diame trther_imaging : categorical ureteral_diame trther_physician : categorical ureteral_diame trther_imaging : categorical ureteral_diame trol_imaging_delay : string urinoma hematuria	08
<pre>filtration_pailoidopr : categorical urinary_tract_ filtration_papedix : categorical filtration_sigmoid : categorical traperitoneal_effusion : categorical inary_tract_duplication : categorical nal_transplant : categorical diversion renal_height renal_volume inter_lithiasis : categorical diftration_sigmoid : categorical interlabial_pe extrasinuss_l pu ureteral_dilat urther_imaging : categorical urther_imaging : categorical urther_physician : categorical trther_physician : categorical ntrol_imaging_delay : string uring : categorical uring : categorical uring</pre>	rinaryTractRes
<pre>littration_appendix : categorical diversion traperitoneum : categorical traperitoneum : categorical diversion traperitoneum : categorical nal_transplant : categorical adder_lithiasis : categorical diversion renal_volume r</pre>	,
<pre>Thitration_signoid : categorical traperitoneal_effusion : categorical traperitoneal_effusion : categorical mal_transplatt : categorical nal_transplatt : categorical tvic_phlebolith : categorical dider_lithiasis : categorical lithiasis : integer ndings : categorical trther_imaging to categorical trther_imaging tre : string trther_physician : categorical ntrol_imaging del : string trol_imaging del : string</pre>	
categorical renal_height inary_tract_duplication : categorical renal_volume nal_transplant : categorical renal_contour_ voluc_phlebolith : categorical renal_contour_ ihisis : integer extrasinusal_p nifings : categorical ureteral_diame ureteral_diame ureteral_diame urther_imaging_type : string pyelocalical_u rther_bysician : categorical ureteral_diame urther_physician_type : string urineterical ntrol_imaging_delay : string urineterical	
<pre>inary_tract_duplication : categorical renal_volume nal_transplant : categorical renal_contour_l volume nal_transplant : categorical renal_parenchy adder_lithiasis : categorical interlabial_pe lithiasis : integer addar_lithiasis : categorical ureteral_diame ureteral_diame ureteral_diame prebrainesican : categorical ureteral_diame prebrainesican : categorical ureteral_diame ureteral_diame prebrainesican : categorical ureteral_diame rther_imaging : categorical ureteral_diame ureteral_diame ureteral_diame trther_physician : categorical ureteral_diame ureteral_diame trther_imaging : categorical ureteral_diame ureteral_diame ureteral_diame trther_imaging : categorical uriteral_diame ureteral_diame urete</pre>	
nal_transplant : categorical renal_contour_ lvic_phlebolith : categorical renal_parenchy ddef_lithiasis : categorical interlaial_pe lithiasis : integer extrasinusal_p ndings : categorical ureteral_dilat trther_imaging : categorical ureteral_dilat trther_imaging_type : string pelviareteric_ trther_physician_tre : string pelviareteric ntrol_imaging_dlay : string hematuria hematuria	
<pre>lvic_phlebolith : categorical renal_parenchy adder_lithiasis : categorical interlabial_pe ndings : categorical extrasinusal_p ndings : categorical ureteral_diame urther_imaging : categorical ureteral_diame urther_physician : categorical pelviceteric_ rther_physician, type : string ureteral_ ntrol_imaging_delay : string hematuria ntrol_imaging_delay : string</pre>	
adder_lithiasis : categorical interlabial_pe lithiasis : integer extrasinusal_p ofings : categorical ureteral_diame urther_imaging : categorical ureteral_diame trher_imaging_type : string pyelocalical_ trher_physician : categorical pelviureteric_ ntrol_imaging_delay : string urinoma hematuria	
lithiasis : integer extrasiousal_p ndings : categorical ureteral_diame rther_imaging : categorical ureteral_dilat rther_physician : categorical pelocaliceal_p rther_physician_type : string pureteral_dilat rther_physician_type : string pureteral_dilat rther_physician_type : string urinoma ntrol_imaging_delay : string urinoma	mal_anomaly
ndings : categorical extrasinosulpi rther_imaging : categorical ureteral_diame ureteral_diame urther_imaging_type : string pyelocalical_ rther_physician_type : string elviureteric_ ntrol_imaging_delay : string hematuria	lvic_diameter
rther_imaging : categorical ureteral_dilat rther_imaging_type : string pyelocaliceal_ rther_physician_type : string pelviureteric_ ntrol_imaging_delay : string urinoma hematuria	elvis
rther_imaging_type : string ureteral_gliati rther_physician : categorical ppelocaliceal_ rther_physician_type : string urinoma ntrol_imaging_delay : string hematuria	ter
rther_physician : categorical ppelviaceal_ rther_physician_type : string pelviaceteric_ ntrol_imaging : categorical urinoma hematuria	ation
rther_physician : categorical pelviureteric_ rther_physician_type : string urinoma ntrol_imaging_delay : string hematuria	dilatation
rtner_pnysician_type : string urinoma ntrol_imaging : categorical hematuria ntrol_imaging_delay : string	
ntrol_imaging : categorical hematuria hematuria	
ntrol_imaging_delay : string	
and strang	_sign
nclusion : string comment	

Figure 3. UML schema of the "computed tomography urolithiasis report" data model

4. Discussion and conclusion

This paper intends to describe an optimal workflow for producing medical imaging report using structured data. The key point is to define mandatory fields to set a simple data model for each domain of application. We think this methodology is an efficient way of iteratively defining such data model, domain by domain, each within an academic research work. We already started to apply this methodology in other imaging exams.

We validated our fields list with only 4 experts. Ideally a larger panel of experts would be necessary. The main advantage of a "small size" expert panel is the high responsiveness, and a shorter time to consensus. For this reason, we decided to propose and publish a data model, and leave the possibility to adjust it later based on feedbacks from medical societies or editors' comments.

As for the rationale of our method in relation to pre-existing interoperability standards initiatives, we initially intended to define simple, light weight, and human readable data models. But it also appears relevant to use and integrate thereafter the successive "light weight" data models as archetypes in the OpenEHR platform [9,14]. Also whenever applicable, some selected elements from FHIR specification should be used in our data model (such as elements from the "ImagingStudy" resource and "MeasureReport" resource of HL7 FHIR v4)[8].

To the best of our knowledge, the use QR-Code to store and transfer structured medical data through the traditional paper-based communication channel has never been described. Recently, Mao et al. proposed a secure way of transmitting medical text data using a video stream of successive QR-Code [15]. We believe this concept can be adapted to the traditional paper-based transmission, and medical imaging report is an example of choice, because being highly domain-specific, it narrows size of the dataset file to be encoded. Also QR-Code scanning in clinical data warehouse might supposedly be more reliable than combining optic character recognition and natural language processing to detect structured data in clinical data warehouse. Further work on QR-Code storage of medical data will focus on compression and encryption methods, to lower the QR-Code size, and secure the access of these data.

We are planning to develop a software for producing medical report based on these tailored data models. This solution is intended to take as input the data model and the mappings, and to produce as an output an enhanced medical imaging report.

References

- Wynia MK, Osborn CY. Health literacy and communication quality in health care organizations. J Health Commun. 2010;15 Suppl 2(Suppl 2):102-15.
- [2] McNair AG, Brookes ST, Davis CR, Argyropoulos M, Blazeby JM. Communicating the results of randomized clinical trials: do patients understand multidimensional patient-reported outcomes? J Clin Oncol. 2010 Feb 10;28(5):738-43.
- [3] Manaouil C, Saliou G, Valléé JN, Jardé O. La loi du 4 mars 2002: comment l'appliquer en matière d'information des patients en radiologie [The law of March 4, 2002: how to implement it with regards to informed consent in radiology]. J Radiol. 2006 Apr;87(4 Pt 1):355-62.
- [4] Mityul MI, Gilcrease-Garcia B, Searleman A, Demertzis JL, Gunn AJ. Interpretive Differences Between Patients and Radiologists Regarding the Diagnostic Confidence Associated With Commonly Used Phrases in the Radiology Report. AJR Am J Roentgenol. 2018 Jan;210(1):123-126.
- [5] Bantug ET, Coles T, Smith KC, Snyder CF, Rouette J, Brundage MD; PRO Data Presentation Stakeholder Advisory Board. Graphical displays of patient-reported outcomes (PRO) for use in clinical practice: What makes a pro picture worth a thousand words? Patient Educ Couns. 2016 Apr;99(4):483-490.
- [6] Goel AK, DiLella D, Dotsikas G, Hilts M, Kwan D, Paxton L. Unlocking Radiology Reporting Data: an Implementation of Synoptic Radiology Reporting in Low-Dose CT Cancer Screening. J Digit Imaging. 2019 Dec;32(6):1044-1051.
- [7] Lehne M, Sass J, Essenwanger A, Schepers J, Thun S. Why digital medicine depends on interoperability. NPJ Digit Med. 2019 Aug 20;2:79.
- [8] HL7 FHIR®. Fast Healthcare Interoperability Resources. Available at https://www.hl7.org/implement/standards/product_brief.cfm?product_id=491. Accessed 2019.
- [9] OpenEHR International. Open industry specifications, models and software for e-health. Available at https://www.openehr.org/. Accessed 2020.
- [10] OMG. Object Management Group. Unified Modelling Language (UML). Available at https://www.omg.org/spec/UML/About-UML. Accessed 2017.
- [11] Ben Kiki O, Evans C, döt Net I. YAML Ain't Markup Language (YAML). 2009. Available at https://yaml.org/spec/1.2/spec.html. Accessed 2020.
- [12] Wright A, Andrews H, Hutton B. JSON Schema. 2019. Available at https://json-schema.org/draft/2019-09/json-schema-core.html. Accessed 2020.
- [13] Martignene N, Lamer A. Goupile. Goupile 2020. Available at: https://goupile.fr. Accessed October 6, 2020.
- [14] Sousa M, Ferreira D, Santos-Pereira C, Bacelar G, Frade S, Pestana O, et al. openEHR Based Systems and the General Data Protection Regulation (GDPR). Stud Health Technol Inform 2018;247:91–5.
- [15] Mao H, Chi C, Yu J, Yang P, Qian C, Zhao D. QRStream: A Secure and Convenient Method for Text Healthcare Data Transferring. 2019 41st Annu. Int. Conf. IEEE Eng. Med. Biol. Soc. EMBC, Berlin, Germany: IEEE; 2019, p. 3458–62.