Design of an Electronic Health Record Module in the Pediatrics Department of the Ouahigouya Regional University Hospital Center

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Abstract. In Burkina Faso, most existing hospital information systems are limited to managing administrative and financial aspects. Computerized tools for managing medical data (clinical, paraclinical, therapeutic, etc.) are almost non-existent. Our goal was to setup a basic HIS in which will be integrated as first module, the very one that is lacking in Burkina Faso's hospitals, a computerized patient records module. The design of this module as well as the hospital information system within which it will be deployed was based on a study of the businesses identified in Ouahigouya regional university hospital center and the interactions of patients with this hospital center. The pediatrics department has been taken as a model for the design of the module. This basic hospital information system with its embedded computerized patient records module has been deployed into the pediatrics department. The designed module allows almost complete digitization of commonly used paper supports (consultation record, medical record, treatment and monitoring sheet) with the resulting advantages (time saving, ease of access to data and statistical reports draw up). This was a very new experience in a reference healthcare center, which can respond to the identified problem.

Keywords: Hospital Information System · Electronic Health Record · eXtensible Markup Language · Enterprise Resource Planning · Business Process Model and Notation · Unified Modeling Language

1 Introduction

1.1 Context

In hospitals, there are some factors that affect the quality of data that are fed back to decision makers. These factors come from the limits and disadvantages of paper supports, because data management are essentially based on these one. Indeed, in Burkina Faso, like the other countries of the French-speaking sub-region [1], few hospitals have an hospital information system (HIS) equipped with an electronic health record module. Most existing systems in these countries are limited to financial management and/or data

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entry [2, 3]. As a reminder, an Hospital Information System (HIS) is a computer system designed to facilitate the management of all medical and administrative information within an hospital [4].

1.2 Problematic

With the large amounts of data that must be processed daily in hospitals, the limits and disadvantages of paper supports (consultation record, medical record, nursing record, treatment and monitoring sheet) are well known. Not only these limitations have analytical implications for decision makers who are at the top of the national health system, but at the lowest level of the ladder, they seriously affect the quality of patient care by the healthcare providers. And this, healthcare providers are the first ones to feel it.

The following observation illustrates the challenges faced by healthcare providers in hospitals clinical departments because of the disadvantages of the paper support. For example, having a patient history and other previous clinical and paraclinical data for the management of a new episode of illness is never easy. Indeed, these data are scattered in health notebooks, sometimes multiple and poorly preserved, or in files stored in the archives and covered in dust and difficult to access in the shortest possible time. Thus, with each new consultation, this obliges healthcare providers to collect the same data again in the consultation register and to completely reconstitute a new medical file, for patients to be readmitted to hospital. This process that we encounter in most clinical departments of hospitals in Burkina Faso has the following repercussions:

- On the efficiency of healthcare providers: the complete reconstruction from scratch of the patient care scenario (collection of administrative data, collection of complaints, collection of the same medical history, prescription of permanent validity test, etc.) delays the patient care due to the time devoted to recreating the medical record; the scattering of previous medical data across multiple files stored in archives, and sometimes in multiple, poorly maintained or unavailable health notebooks, make it difficult for healthcare personnel to easily reconstruct the patient's medical history;
- On the patient: the re-prescription of exams whose results remain valid for the patient's entire life (such as blood type and hemoglobin electrophoresis) obliges the patient to spend money again for the same exams if healthcare personnel are not able to access previous results (unavailable health notebook or no notification of these exams results in the health notebook), resulting in a financial impact;

Then, when it comes time to compile data for statistical purposes, the following factors negatively impact the quality of the transmitted data, compromising the quality of data to the higher authorities of the system:

- Incompleteness of data due to non-reporting of important items;
- Data sometimes illegible due to poorly written handwriting style of some healthcare agents;
- Inconsistency of some data attributable to human error;

The use of a computerized system for managing patients' medical data helps to address these problems [5].

1.3 Objectives

General Objective. The general objective was to design an Electronic Health Record (EHR) module in a clinical department of a reference healthcare center in Burkina Faso, which takes into account the specific needs of the target users. This clinical module should address the problems posed by paper-based records.

Specific Objectives. The specific objectives were as follows:

- Design an EHR module that meet the definition of the International Organization for Standardization (ISO) based on the paper-based records to be digitalized and the business processes characterizing the target clinical department.
- Deploy this EHR module within the target clinical department.
- Evaluate the implementation of this module.

2 Methodology

We present in the following subtitles the framework of our work, then essential and critical aspects on which it seemed essential to us to look into by way of preparations for our design project: the method of unique patient identification, the modeling of our EHR, the standards and references to be used.

2.1 Project Framework

The Ouahigouya Regional University Hospital Center is a reference healthcare center in the northern region of Burkina Faso. The pediatrics department of this center was the site where we set up and implemented our EHR module.

The management of patients' medical data is exclusively done using paper supports. The pediatrics department includes an emergency unit, a hospitalization unit, a neonatology unit, and a Nutritional Recovery and Education Center. The pediatric emergency unit receives urgent cases, referred patients, evacuated and transferred patients, every day of the week, 24 h a day. Seventh year medical students participate in patient care and continuity of care. They are the first point of contact for the service with patients received in this unit. Physicians and physician assistants provide outpatient consultations and also visit patients in the hospitalization unit.

The entire process of collecting and managing patients' medical data relies exclusively on paper-based system, including consultation registers, hospitalization registers, medical records, nursing records, treatment and monitoring sheets, medical test order, prescriptions, and hospitalization discharge summaries.

2.2 Norms and References

The content of the medical record generated by our EHR module must reflect the terminological characteristics of medical language. To achieve this, we have defined norms and references to be used.

Types of Data. Our EHR module will be designed to manage textual data and iconographic data (images). Textual data will be stored in the form of structured data, while iconographic data (images) will be stored in the form of semi-structured data (a string of characters encoded in base64 format).

Terminological References. The terminologies used in filling out certain items will be based on predefined lists of terms specific to different domains of healthcare:

- The terminology of symptoms is based on a list of validated terms derived from medical vocabulary;
- At the level of diagnoses, two entities should be distinguished:
  - The diagnoses suggested at the hypothesis stage (diagnostic hypothesis) may sometimes include imprecise terms, as they may include "groups or families of pathologies" that will need to be refined later. The terminology used at this stage is based on a merged list of terms from the common medical vocabulary and a disease dictionary;
  - The final or definitive diagnoses: they result from refining or adjusting the diagnostic hypothesis after confirmation medical exams. These diagnoses have a higher level of precision and can be coded. The terminology of the diagnoses used at this stage is based on the International Classification Diseases, 10^{th} revision (ICD-10);
- The terminology of medications is based on the International Nonproprietary Name (INN), also known as the common or generic name of the medication;

2.3 The Unique Patient Identification Method

Our EHR module has been designed to assign a unique identifier to patients. The chosen identification method uses a simplified version of the one implemented by Barro et al. [6] in Burkina Faso. The algorithm takes as input a string of characters resulting from concatenating strict identification traits (last name, first name(s) and date of birth) and complementary identification traits (mother's maiden name and first name(s), father's name(s) and last name). The steps of this algorithm are as follows:

- Processing of the data: All data are converted to uppercase (last names and first names). Accented characters are replaced by their unaccented equivalents. If there is more than one first name (for the patient, his mother or his father), these first names are organized in alphabetical order.
- Hashing: The resulting string of characters is hashed using the SHA 512 algorithm.
- Selection of the first 8 characters of the string resulting from this hashing.

2.4 The EHR Characteristics

Architecture. The International Organization for Standardization (ISO) defines the EHR as "a repository of information regarding the health status of a subject of care, in computer processable form, stored and transmitted securely and accessible by multiple authorized users, having a standardized or commonly agreed logical information model

that is independent of EHR systems and whose primary purpose is the support of continuing, efficient and quality integrated health care" [7]. The literature reports three types of Electronic Medical Record (EMR) structures, according to Hayrinen et al. [8]:

- Time-oriented EMR: data is presented in chronological order;
- Problem-oriented EMR: notes are taken for each problem assigned to the patient, and each problem is described according to subjective information, objective information, evaluations, and the plan of care (SOAP structure);
- Source-oriented EMR: the content of the record is organized according to the method by which the information was obtained, for example, visit notes, radiography reports, and blood analyses. In each section, data is presented in chronological order;

EMR systems typically combine these three types [8]. To ensure that our clinical module generates an EHR that meets the ISO definition and structures the data according to the types described above, we designed it with the following concept. We conceive the EHR as a unique object that should integrate a summary of all patient data (administrative, clinical, paraclinical, therapeutic, and medical history information). Its content should not be fixed but should be continuously updated and evolved through the addition of new data resulting from all medical events that occur during the patient's life. The entire patient history should be contained within this object. It should be attached to one and only one patient and should contain a unique instance for the patient owner. The variety of data to be grouped within the EHR requires organization. We proposed to structure our EHR according to the organizational tree presented in the Fig. 1:

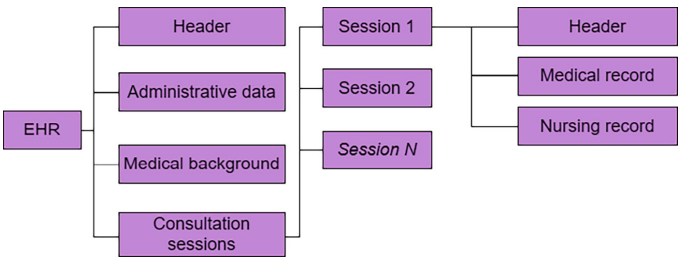

Fig. 1. The EHR Organizational tree

The data in the EHR is divided into four main sections: header section, administrative data section, medical background section, and consultation session section. Consultation sessions correspond to the medical events experienced by the patient, such as consultations and medical procedures. The data within a session is further divided into sub-sections, such as heard, medical record, nursing record, and so on. Consultation sessions are arranged chronologically, and the data is sourced from the various healthcare providers and services that the patient has received care from, so that the complete medical history of the patient is contained within this single object. Such a synthetic object allows for both a temporal (evolution over time) and transversal (interdepartmental) analysis of the data.

The XML Format. To implement the architecture and concept we plan to adopt for our EHR, the disaggregated data provided to our clinical module will be processed and compressed into a single data format using XML [9]. The advantages of this concept are those inherent in the XML document format:

- When the EHR formatted in XML is retrieved as a single block from the database, it becomes an object that can be queried and manipulate using XPath and XQuery [10];
- As XML is the standard data exchange format between information systems [9], any information system or application, regardless of its nature and execution environment, can easily browse and extract specific data from this EHR formatted in XML;

Figures 2 and 3 provide an overview of the XML structure of our EHR. For better presentation and readability, we are formatting this document using an XSL style sheet.

```
<root version="1.0" xmlns:xsl="http://www.w3.org/1999/XSL/Transform">
    <idDossier></idDossier>
    <idHopital></idHopital>
    <dateCreation></dateCreation>
    <dateDerniereModification></dateDerniereModification>
    <profil>
        <nom></nom>
        <prenoms></prenoms>
        <sexe></sexe>
        <dateNaissance></dateNaissance>
        <statutMatrimonial></statutMatrimonial>
        <profession></profession>
        <carteIdentite></carteIdentite>
        <niveauInstruction></niveauInstruction>
        <mutuelles></mutuelles>
        <assurance></assurance>
        <nomPere></nomPere>
        <prenomsPere></prenomsPere>

            <chirurgicaux></chirurgicaux>
            <gynecoObstetriques></gynecoObstetriques>
            <vaccinaux></vaccinaux>
        </personnels>

        <familiaux>
            <ascendants></ascendants>
            <collateraux></collateraux>
            <descendants></descendants>
        </familiaux>
    </antecedents>
    <sessions>
        <session></session>
    </sessions>
</root>
```

Fig. 2. XML structure of the EHR (version 1.0).

2.5 The Hospital Information System Architecture

Our EHR module will be designed as a component of a Hospital Information System (HIS). To do this, we needed to lay the foundation of a basic HIS, of which the EHR will

```
<session>
    <idSession></idSession>
    <idHopital></idHopital>
    <service></service>
    <dateEnregistrement></dateEnregistrement>
    <dateDerniereModification></dateDerniereModification>
    <modeEntree></modeEntree>
    <modePec></modePec>
    <ficheTetu></ficheTetu>
    <ficheReferenceEvacuation></ficheReferenceEvacuation>
    <etatSession></etatSession>
    <rendezVous></rendezVous>
    <structureProvenance>
        <type></type>
        <departement></departement>
        <province></province>
        <region></region>

        <hypothesesDiagnostiques></hypothesesDiagnostiques>
        <resumeSyndromique></resumeSyndromique>
        <examensParacliniques></examensParacliniques>
        <resultatsExamens></resultatsExamens>
        <traitements></traitements>
        <iconographie></iconographie>
        <commentaires></commentaires>
    </dossierMedical>
    <dossierInfirmier>
        <evaluationEtat></evaluationEtat>
        <patientARisque></patientARisque>
        <traitementsAdministres></traitementsAdministres>
        <surveillance></surveillance>
        <actesPoses></actesPoses>
        <commentaires></commentaires>
    </dossierInfirmier>
</session>
```

Fig. 3. XML structure of the "session" node

be one of the first components. Other modules may be added later to eventually form a complete HIS.

The proposed HIS model will be an Enterprise Resource Planning (ERP) model [11], as it is a model that allows us to establish the plan of an information system and ensure perfect integration and interoperability of its subsystems [1]. An ERP system consists of a set of modules that work together, relying on a common database to support all of its features. It offers the advantage of providing a highly structured approach to managing organizational resources. We have adopted a patient-centered process approach [12].

To build the plan of our HIS, we considered the interactions of the patient with the different services identified within the hospital and analyzed the sequences of activities that occur within them. Following this analysis, we proceeded to model the processes that we were able to identify.

To have a detailed and visually appealing representation of the business processes that occur within the different services, we have constructed Business Process Model and Notation (BPMN) diagrams [13]. BPMN is a modeling language used to represent an

organization's business processes through a graphical representation. This language is designed for the analysis and design of business processes that involve the interaction of different systems. BPMN is complementary to the Unified Modeling Language (UML), which focused more on the analysis and design of information systems. Figure 4 shows BPMN diagram that describe the processes that occur in the emergency unit of the pediatrics department.

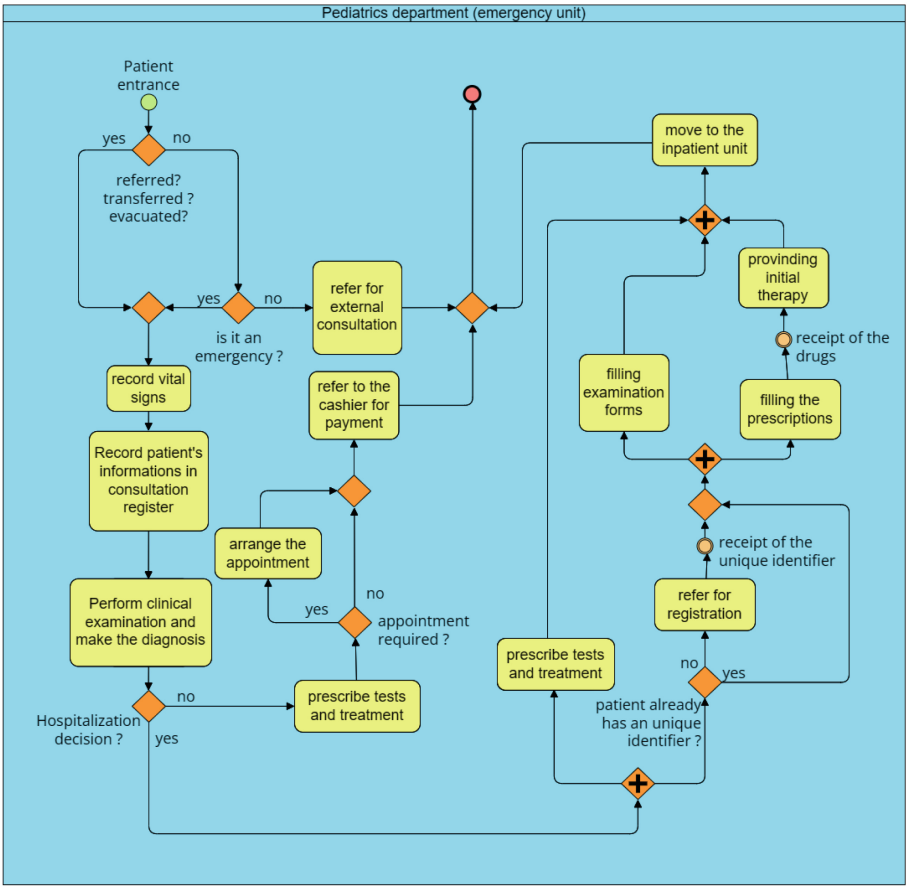

Fig. 4. Businesses processes in pediatric emergency unit

The HIS is a stack of independent modules that are connected to a common database. For each department to be included in the HIS, a module will be designed. However, for the scope of this project, only two modules will be designed: the EHR module intended for clinical departments, and a basic system administration module that will handle user management. Figure 5 presents the network architecture of the HIS.

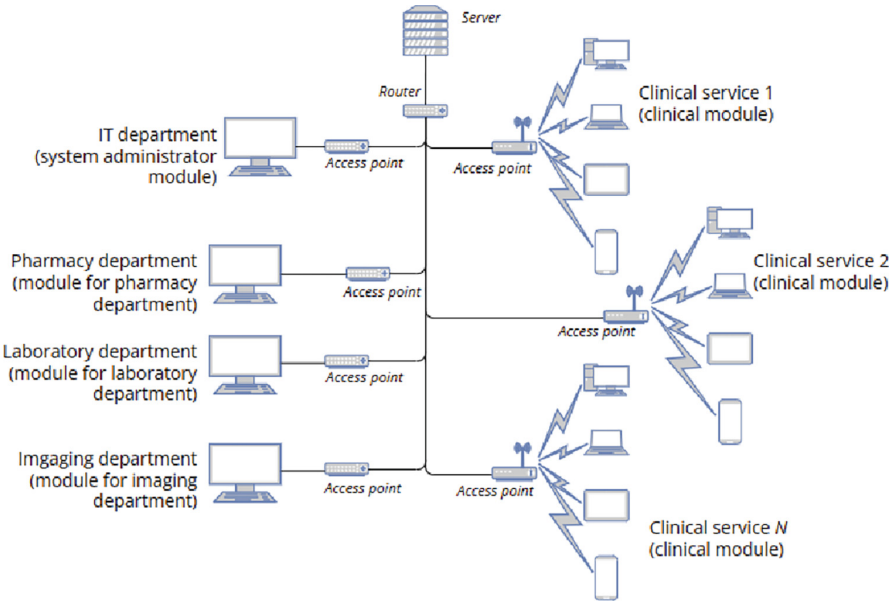

Fig. 5. The HIS network architecture

2.6 The EHR Module Architecture

Our EHR module is a web-based application that adopts a 3-third architecture [14], with the following layers: presentation layer, processing layer, and data access layer. We used the "MVC" design pattern provided by Symfony [15] Framework to build this module according to this architecture. Figure 6 shows the 3-third architecture adopted for our EHR module.

2.7 Database Modeling

The database modeling of our system was done as follow. Based on the consultation and hospitalization records, medical and nursing records, as well as monitoring and treatment sheets, we established a data dictionary and identified the entities involved in the processes of the pediatrics department, as well as the relationships and cardinalities between these entities. We used the Looping [16] modeling tool to construct the graphical representation of our conceptual data model. Figure 7 shows this conceptual data model. Depending on the type of value to be assigned to the properties, the types of data used are: Varchar, Int, Date, Datetime, Logical (Bool), Text. The properties of the entities correspond to the fields (columns) of the database tables. Some fields are intended to receive composite data (semi-structured data). We used JSON and XML objects to organize these data. The data type corresponding to these objects at the database level is the CLOB (Character Large Object) type, also designed as TEXT.

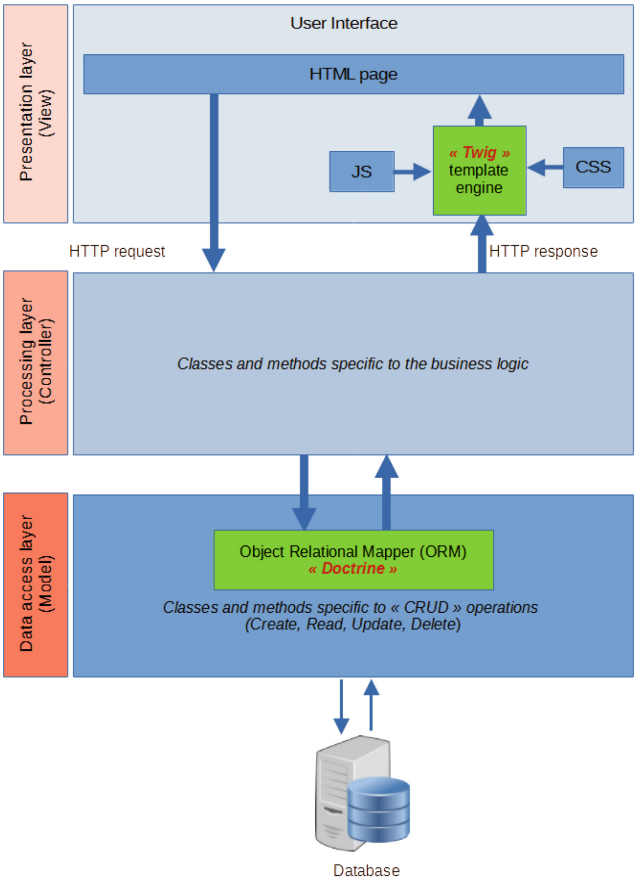

Fig. 6. Three-third architecture of the clinical module

2.8 UML Modeling

In this subsection, we present the following UML diagrams, which respectively describe the functional and dynamic characteristics of our module:

– The use case diagram (Fig. 8)
– The sequence diagram of two main scenarios (Fig. 9, Fig. 10)

2.9 Technologies and Development Environment

The development tools and technologies we used are as follow:

– Back-end languages. We used PHP as the main scripting language, and JavaScript for certain AJAX [17] requests.
– Front-end technologies: HTML, JavaScript, and CSS were used for the visual rendering of the graphical interfaces. In Symfony, the template engine used for assembling and constructing HTML pages is Twig [18];

– Web server: We used WampServer [19] as the application server;
– Database: we used PostgreSQL [20] as the database management system;
– Development environment: we used Visual Studio Code [21] as code editor;

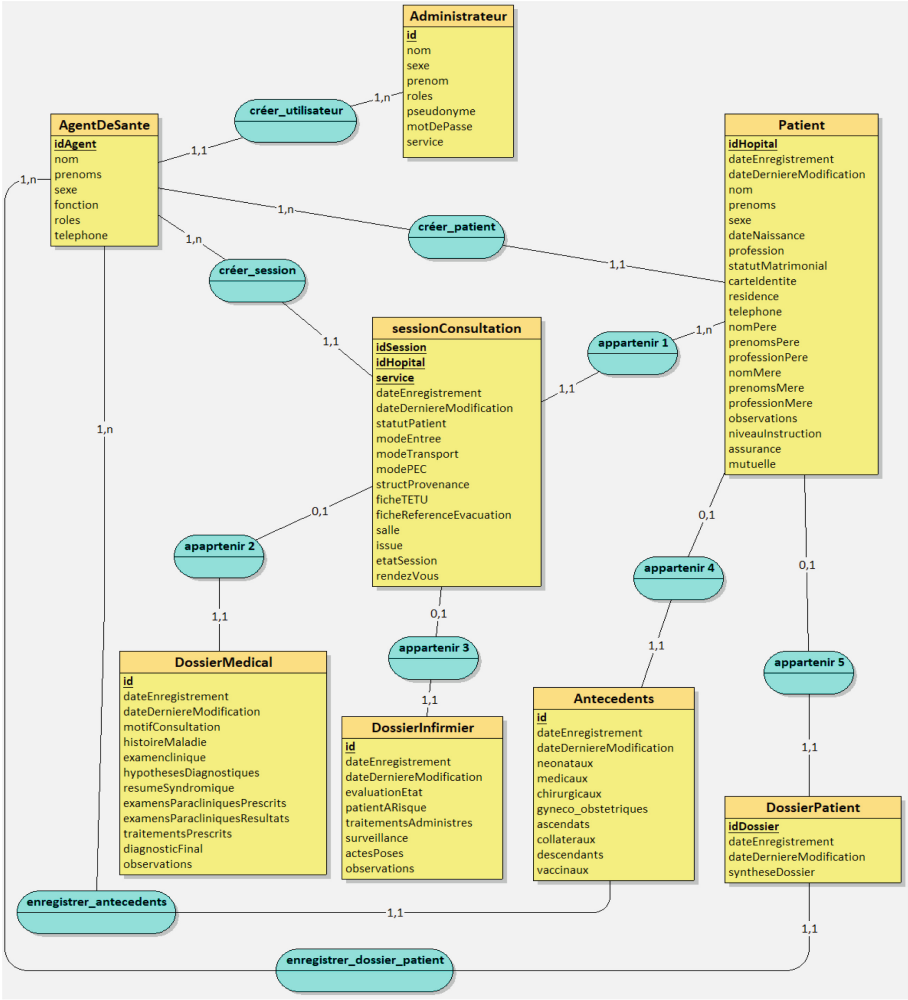

Fig. 7. Conceptual data model of the clinical module

2.10 Deployment of the Module

Our basic HIS and the clinical module it integrates were deployed within the pediatrics department after setting up and configuring a secure wireless local area network (Wi-Fi). The components of the entire system implemented are:

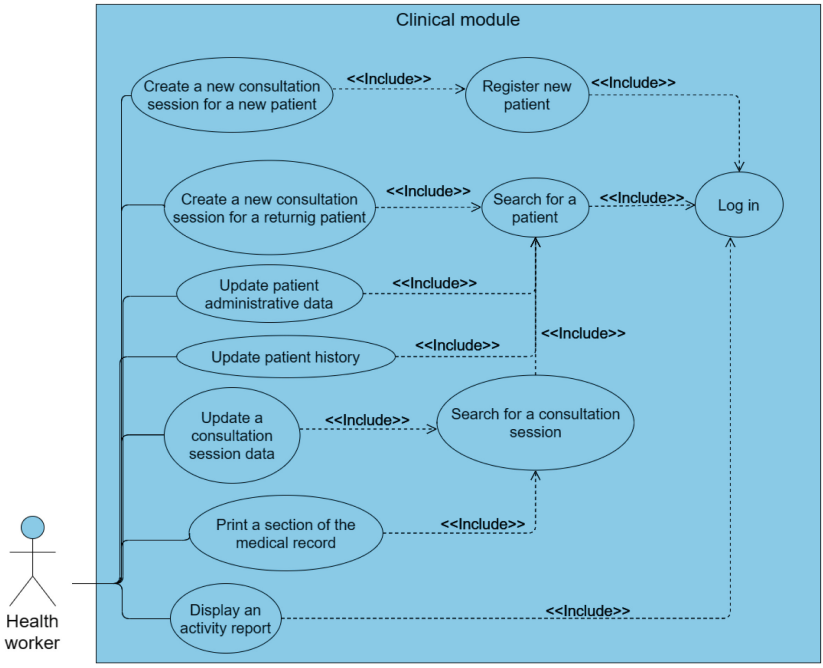

Fig. 8. Use case diagram

- The server: the server used is a desktop computer equipped with the Windows 10 operating system, configured as a server. It was installed in one of the rooms of the pediatrics department. A fixed IP address was assigned to it. The application server on which our module runs is WampServer;
- The local network: The local network set up is a wireless network. The access point used emits a low range signal, which is amplified by two repeaters, so that it is possible to connect to the application from different rooms of the department;
- The client devices: The client devices from which users access the module are smartphones, tablets, laptops and desktop computers (able to connect to the wifi signal);

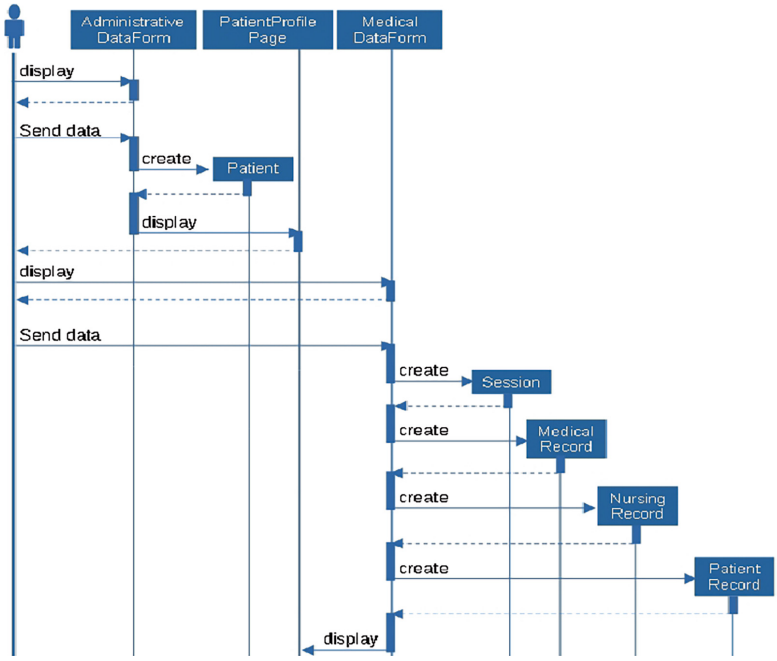

Fig. 9. Sequence diagram: create a new consultation session for a new patient

3 Results

3.1 The Generated EHR

Our EHR module called *"iDossier"* allows generating an EHR as presented below in its version 1.0. In accordance with our concept and the structure we have defined in our methodology, the EHR presented in the illustrations below is a unique XML object, loaded from the database, and then formatted using an XSL style sheet.

This XML document, attached to one and only one patient, contains all the patient's data (history, administrative, clinical, paraclinical, and therapeutic data), collected for each episodes of illness. Any intervention on the patient's data (recording a new episode of illness, recording or updating clinical, paraclinical, or therapeutic data) results in an update of this synthetic XML document, either by adding new nodes (new data) or by modifying nodes (updating data).

This single document allows for both a vertical observation of data (within a single department) and a cross-sectional observation (across different departments). It is possible to navigate within this file by expanding the nodes. Since it is an XML document, XQuery or XPath queries can be used to extract and cross-reference data as needed (Figs. 11, 12, 13 and 14).

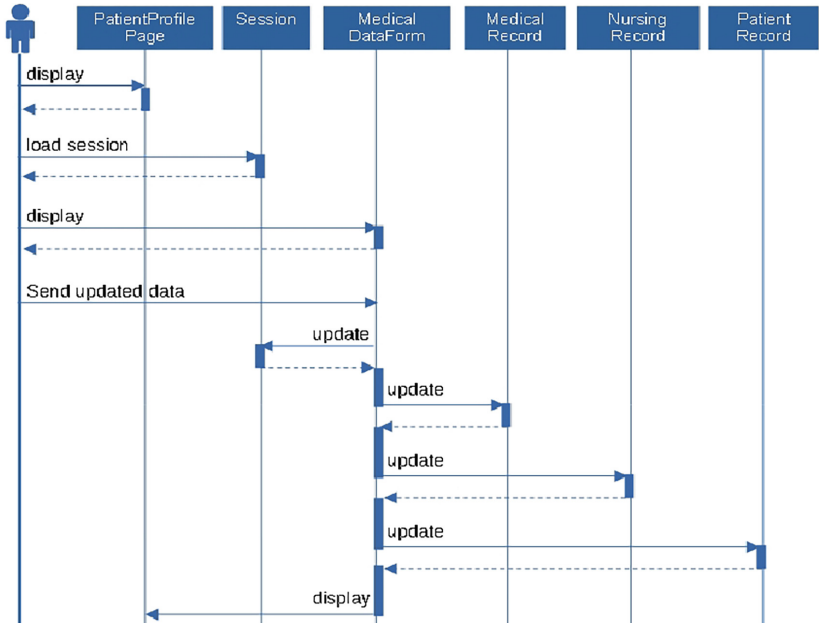

Fig. 10. Sequence diagram: update a consultation session

Fig. 11. The Electronic Health Record, with its four sections "header", "subject profile", "histories" and "sessions".

3.2 Implementation of the Module in the Pediatrics Department

The implementation of the module within the pediatrics department began on January 9th 2023. The first users involved were seventh year medical students and physicians. The routine that we put in place is as follow:

- In the emergency unit, all patients received (outpatients and patients to be hospitalized) are first recorded. This is immediately followed by the collection and recording of "medical data". This recording generates a digital version of the medical record in its entirety. The treatment and vital signs grid, constituting a part of the nursing record, is also generated for patients to be hospitalized;
- In the hospitalization unit, updates to the medical records of hospitalized patients during visits are made directly in their digital medical record;

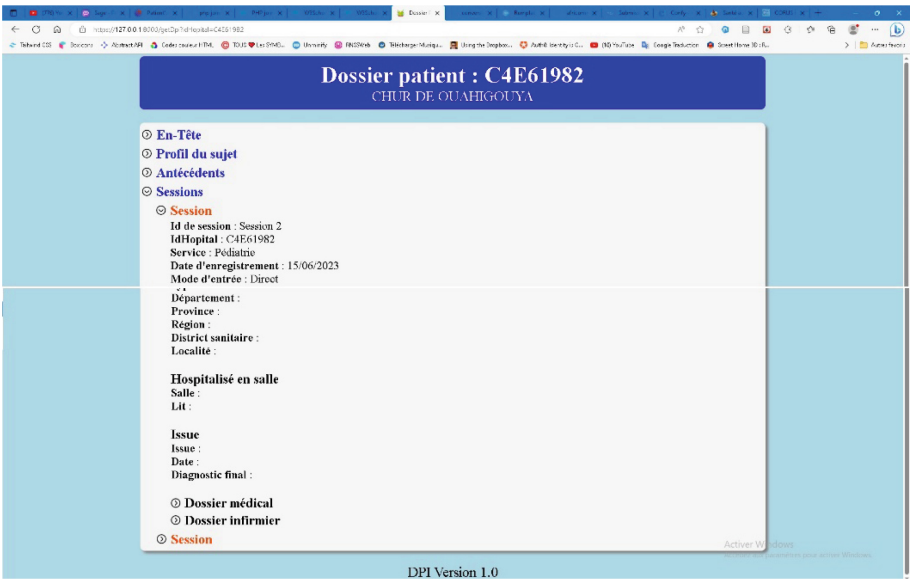

Fig. 12. An overview of a "consultation session" node, containing the corresponding consultation header data and the "Medical Record" and "Nursing Record" nodes, which respectively contain the data from the medical record and nursing record attached to the current episode of illness.

Fig. 13. An overview of the "Iconography" node. This node belongs to the "Medical Record" node and displays the iconographic data (imaging, printed examination report captures, and other photographs).

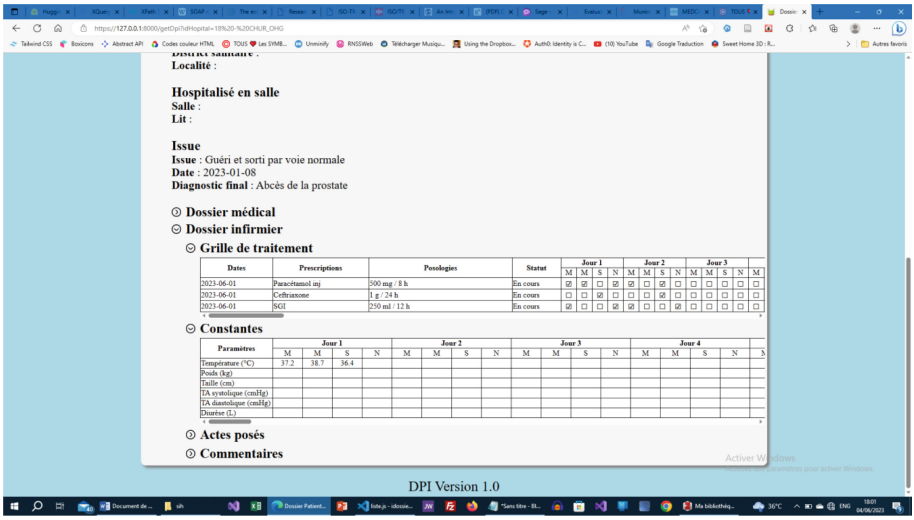

Fig. 14. An overview of the "Treatment grid" and "Vital signs grid" in the "Nursing Record" node.

- Interacting with the data from mobile devices (smartphones and tablets) allows users to be mobile during their tasks and instantly access these data from the patient's bedside;
- The statistics functionality offers tables that allow real-time notification of the received pathologies. The data available makes it easy to generate statistical reports;
- A physical version of the medical record can be obtained at any time by printing the digital version;

3.3 Users Adoption

The users have adopted the system put in place because we were able to convince them of the ease and benefits that digital management of patient data can bring.

3.4 Impact and User Experience of the Module

To evaluate the impact and user experience of the module among users, we administrated a questionnaire to the users who numbered 7 (the seventh year medical students). Among these seven users:

- All of them (7/7) said that the user interface is user-friendly;
- Five users (5/7) said that the functionalities meet all their needs;
- Only two users (2/7) said that the module offers them a time-saving benefit;
- All of them (7/7) said that searching for and accessing patient data is easy;
- Six users (6/7) said that using the module is easy;

3.5 Difficulties and Limitations

Lack of a Performant Network Infrastructure. The Ouahigouya Regional University Hospital Center does not have a usable network infrastructure for the implementation of our module. Some local networks exists, but they are intended for other purposes.

Logistical Difficulties. The local network was not steady. This sometimes caused interruptions or difficulties in connecting and accessing the module. During power outages, the absence of an uninterruptible power supply required the server to be manually restarted when power was restored.

Difficulties Related to a Lack of Training. The time we had for users training was insufficient. The difficulties in using the module were due to gaps resulting from this lack of prior training and practice.

4 Discussion

4.1 Technology Used

Our EHR module is based on web technologies. This type of technology is mature, proven, and offers ease of use and deployment [1]. For users, there are no constraints in terms of terminal compatibility. Any terminal (smartphone, tablet, laptop, and desktop computer), as long as it has a web browser that meets current standards, can be used to access the module.

Some systems have been designed as desktop applications. This is the case, for example, with MEDCAB in Cameroon [22]. While a desktop application requires each user to have a computer, the same is not true for a web application like ours. In the scenario we have established, tablets and smartphones were sufficient and much more practical for recording, updating, and consulting patient data, both in the reception and treatment room of the emergency unit and at the bedside of patients in the hospitalization unit.

4.2 Deployment of the Module

Setting up an HIS requires a network infrastructure that allows for the interconnection of the different departments of the hospital. The context of our work did not provide this framework. The HIS integrating our EHR module was thus deployed on a computer that served as a server, installed within the pediatrics department itself. In the context of the experimental implementation of the module, such a deployment may be sufficient, but the data cannot be shared with other departments.

4.3 Functional Coverage

A complete HIS integrates a set of modules and functionalities intended to meet the needs of the departments within the hospital [23]. Our HIS is in its embryonic stage and integrates only the bare essentials. The clinical module, which was designed based

on the common needs in the pediatrics department of Ouahigouya regional university hospital center, includes only the functionalities related to the most commonly observed processes in the pediatrics department. The module as well as the HIS that houses it have been designed to easily accommodate future developments.

4.4 Users Adoption

All staff in the pediatrics department recognized the difficulties in managing and exploiting data related to paper-based records. Physicians, health assistants, nurses, as well as 7th-year intern trainees, embraced the implemented computer system. Other studies dealing with the implementation of EHRs in healthcare centers also mention good adherence by healthcare staff [1, 24, 25].

4.5 User Experience

The negative points identified in the user experience evaluation are mainly that the module does not offer a time-saving advantage compared to paper-based supports (5 of the 7 users). The reasons for this negative feedback were mainly the inability to provide users with adequate training beforehand. Indeed, the conditions for a good training on the use of the module were not met. The time allocated for training was only 3 h, just enough to present the interfaces and the functioning mode of the module. There was not really a training session. In addition, one of the users had not been able to attend the very short training session.

4.6 Challenges

In the implementation of our EHR module, we noted challenges that hindered the proper functioning of the system put in place. These included the absence of a performant network infrastructure, instability of the local wireless network setup, frequent power outages, and insufficient user training. Studies related to the implementation of EHRs in developing countries have also identified these same challenges [26, 27]. The malfunctions attributable to poor quality of the local network and power outages were not only causing frustration among users but also leading to parallel use of physical records. It is therefore crucial to address these challenges in order to fully harness the potential that an EHR can bring. To tackle these challenges, the commitment of hospital leaders and healthcare authorities in the country to EHR implementation should be one of the primary determinants. These leaders and authorities should prioritize EHR implementation programs. It is through the determination of these leaders that solutions to the various barriers we have observed in our EHR implementation will emerge. According to *Odekunle et al*., facilitating factors for EHR implementation in Sub-Saharan African countries include implementation planning through the definition of realistic goals, initial and ongoing user training, financial support from authorities, and the adoption of an appropriate system [26].

5 Conclusion

Based on a systematic study of the needs and business processes of the pediatrics department of Ouahigouya regional university hospital center, we designed and implemented the embryo of an HIS integrating an EHR module. The processes that run in this department are standard processes found in most clinical departments and other hospitals. The result we have achieved can therefore be transposed to other clinical departments and, consequently, to other hospitals. Our work is a first experimental local implementation of its kind in a reference healthcare center in Burkina Faso. The multilateral monitoring we carried out during this implementation allowed us to identify the essential factors for a successful integration of digitalization within our healthcare centers. It remains that the first responsible parties of these centers and health authorities need to be more involved in supporting this integration through concrete measures.

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