Modelling Patient Medication Usage in Secondary Care Research Systems

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***Abstract*—Medication usage and administration are key areas for standardisation and interoperability in specialty-agnostic, secondary care research systems. Based on the requirements of four medical research specialty areas in Central England, we developed a medication record model, for the purpose of keeping track of medications the patients are taking, both from a patient-care and future research-participation perspectives. In this paper, we present the model that is flexible enough to capture the core requirements of all research specialty areas, but also extensible to include more specific, non-generic requirements. This work supports the electronic health data standardisation and interoperability efforts within the secondary care domain.**

Keywords-standardisation; electronic health record; patient medication

I. INTRODUCTION

The interoperability and standardisation of medical information in secondary care is an ongoing challenge, also reflected in secondary care research, where information is collected, processed, queried and exchanged for clinical studies within various specialty research areas. A recent report [1] highlighted the disparity between the primary and secondary care sectors, in terms of the systematic application of information technology in healthcare. In the eight countries studied, secondary care adoption of health information technology and health information exchange was behind that of primary care. This was particularly the case in England.

Our work aims to find solutions towards the increased interoperability and standardisation of information in secondary care research. One specific area focuses on patient medication recording, that is, the recording of medications administered to patients by healthcare professionals, and also other medications self-reported by the patients. Medication usage information is necessary for the clinical care of the patient—the knowledge of treatments for particular conditions; for safety—the interactions of drugs; and for including or excluding patients from participation in clinical studies.

In this paper, we present a patient medication model, developed to capture the requirements of four research specialty research areas: asthma, bronchiectasis, chronic obstructive pulmonary disease (COPD) and early arthritis. While medication recording is common to all four, the level of detail captured varies. The proposed model captures the links between medication, patient and healthcare professional; and it also fits within the extensible **C**omprehensive **U**nified **Re**search (CURe) framework for developing secondary care research systems. Our model builds on existing efforts by the English National Health Service (NHS), such as the dictionary of medicine and devices (dm+d) [2], prescribing model [3] and dose syntax model [4]. Our medication model addresses a specific context—monitoring medication usage by patients—and differs from the contexts addressed by e-prescription, medication adherence and management, which are the focus of many of the research work on the subject of medication. Although the model describes the set of medication data elements useful for secondary care research registries, we will illustrate the data items recorded in the CURe applications for the four specialty areas.

II. RELATED WORK

Our work currently applies to the Central England region and as such, we have looked into the models used by the NHS, the main provider of healthcare. We have also considered relevant work in the literature regarding the medication datasets and their standardisation.

A. Prescribing and Dose Syntax Models

In July 2012, the NHS adopted the dm+d as the standard dictionary of medicines licensed in the United Kingdom [5]. The dm+d is the basis for all medicine and device codes forming the SNOMED CT UK Drug Extension, following the need to integrate dm+d with the Systematized Nomenclature of Medicine Clinical Terms (SNOMED CT), the NHS strategic clinical terminology solution, necessary for the interoperability of electronic health records [6,7]. Dose-based prescribing is normal practice in secondary care [3]. On paper, this combines the generic drug name (virtual therapeutic moiety, VTM), dose, route and frequency, for example: Paracetamol (drug name), 500 mg (dose) — oral (route) — qds

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(frequency, Latin abbreviation for four times a day). In electronic prescribing systems, the dm+d implementation guide suggests using VTM concepts to prescribe generically, while taking into account some exceptions and the prescribing rules [3]. The dm+d is structured around five key components, ranging from a generic drug (VTM, e.g. Atenolol) to an actual medicinal product pack (AMPP), which is drug manufactured by a specific supplier with the drug having form and strength values, e.g. Atenolol 100 mg tablets (Alpharma) x 28 tablet.

Although the dm+d provides a standard description and electronic identifier for medicines, there is no standard structure for representing dosage instructions, for example, "take two tablets three times a day". Without standardisation, this information can only be sent and stored electronically using free text. Work is ongoing to develop standard dosage syntax so that this information can be sent in a standard coded format, which will enable diverse clinical systems to manipulate the data transferred, for example calculate a dose or quantity. This will also improve patient safety by standardising the way that dosage instructions are communicated and reducing the potential for misinterpretation. The dosage syntax model was developed by the NHS Information Authority in conjunction with the international health standards organisation, HL7 [8, 9], with a cut down version of the dose syntax model for e-prescribing [10].

B. *Medication Datasets*

A number of related projects on electronic health records have defined datasets for medication, with different usage to supporting research. MyMedicationList [11] is a prototype application that helps users to manage their personal medication record. The medication record is based on a document model that captures the medication name, interval, quantity, frequency, patient instruction, indication, available generic substitute of a branded drug, prescriber and supplier.

The Continuity of Care Record (CCR) schema is a core dataset of the most relevant administrative, demographic, and clinical information facts about a patient's healthcare [12]. It is one of suite of standards for health information systems used in the United States, developed to organise and make transportable a set of basic healthcare information that can be accessed by medical practitioners and patients. The CCR schema defines a medication object to describe a patient's current medications. Similarly, openEHR [13] develops open specifications for health information systems. For medication management, openEHR has identified data groups relating to medication order or administration [14].

The above works have informed our medication model, developed to capture routine medication usage information useful for research studies. The following sections describe how our model captures user requirements, and its implementation within CURe.

III. SCOPE AND CONTEXT OF WORK

A. *CURe Framework*

The CURe framework has been developed as part of the design and development of a research system to be used for clinical research databases and clinical studies across multiple research specialty areas in secondary care. The extensible framework adopts a modular approach to solve some of the problems of localised clinical research systems, where a system is built for a single clinical unit to solve immediate localised problems, without considering the possibility of similar requirements from other units or research specialty areas, irrespective of location [15]. User requirements are used to build generic models of common data elements between specialty areas. By using an extensible design pattern, the common elements create scalable object oriented taxonomies designed around generic and non-generic data objects. Our work also includes an adaptation and implementation of technical standards, especially in data recording, which facilitates interoperability across research systems for different specialty areas.

B. *User Requirements*

The knowledge elicitation process, aided by the participatory approach with the domain experts, led to the gathering of the medication recording needs of users in the four research specialty areas. The common data items include generic drug name; drug category; active ingredient (name, strength); dosage (value, unit); start and stop dates; frequency. Other data items include brand name; and route of administration.

IV. MEDICATION MODEL

Based on the user requirements and the medication standardisation decisions, we present the core medication model, as well as aspects of the extended model that cater for some of the additional requirements within CURe.

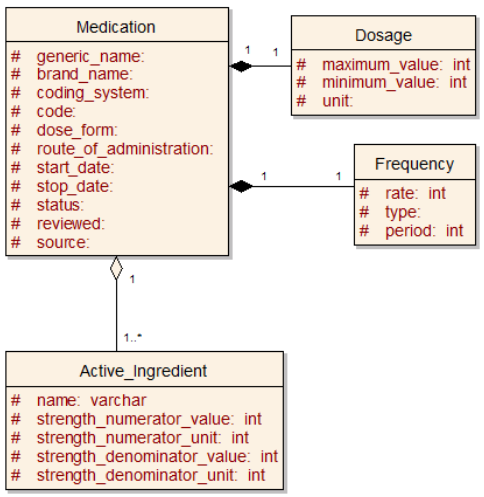

Figure 1. Medication entity model

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The entity model (Figure 1) presents the components of the medication model, specifically highlighting their relationships from an architectural design perspective.

A. Medication Data Group

Medication-related data elements are presented in Table 1. The last three rows are attributes relating to the links among medication, patient and healthcare professional, that we model in CURe for validation and auditing purposes. The second column of Table 1 describes each data element and gives examples of what data values we have used in CURe. The generic drug name is a key element in this group. In CURe, we adopted the NHS dm+d VTM for the standardised generic drug names as used in the UK. Similarly, to make the drug information interoperable, we are using SNOMED CT codes to uniquely identify each generic drug. This has an advantage over the British National Formulary [16], which, although widely used by healthcare professionals for prescribing, it does not have unique codes for drugs. For users who want to specify the brand name, we are using the SNOMED CT Trade Family concepts. For data values, such as units of measure, frequency and route of administration, we have used dm+d editorial policy guidance and international standards where applicable.

Table 1. Medication model.

Attribute		Description/Usage in CURe
Generic drug name		dm+d VTM or VMPs with no VTM parent
Brand name		SNOMED CT Trade family
Coding System		SNOMED CT
Code		SNOMED CT Term ID
Active Ingredient (1..M)	Name	e.g. Amoxicillin
	Strength Numerator Value	500 in 500mg (strength is of an available product)
	Strength Numerator Unit	mg in 500mg
	Strength Denominator Value	e.g. 5 in "Amoxicillin - 125mg/5ml oral suspension"
	Strength Denominator Unit	e.g. ml in "Amoxicillin - 125mg/5ml oral suspension"
Dose Form		e.g. tablet, capsule
Dosage	Minimum Dose Value	Quantity of medication to be taken or administered at one time
	Maximum Dose Value	If only one recommended dose, use the maximum dose.
	Dose Unit	"mg" in 60 mg
Frequency		e.g. once a day, hourly
Route of Administration		e.g. oral route
Start date		Date the medication is started
Stop date		Date the medication is stopped
Status		Medication continued or stopped
Medication reviewed		Medication check at a patient visit
Source		Source of the medication information.

B. Medication Record Examples

Based on the above model, we now show how the two example records are represented. Example 1 (Table 2) shows a medication where the application user is interested in recording the dosage, rather than the strength of the product. Example 2 (Table 3) is a combination drug, where the two active ingredients are important for the medication recording.

Table 2. Example 1: An Arthritis patient using Naproxen, a maximum of 1 gram daily.

Attribute		Value
Generic drug name		Naproxen
Coding System		SNOMED CT
Code		DescriptionID (20444015)
Dose Form		Tablet
Dosage	Maximum Dose Value	1
	Dose Unit	g
Frequency		1 time in 1 day (daily)
Route of Administration		Oral
Start date		15/06/2010
Stop date		
Status		Ongoing
Medication reviewed		Yes
Source		Other CURe specialty area prescription (verified)

Table 3. Example 2: A COPD patient is on Seretide, a combination drug of Fluticasone + Salmeterol, 500 micrograms/50 micrograms, 1 puff, twice a day.

Attribute		Value
Generic drug name		Fluticasone + Salmeterol
Brand name		Seretide
Coding System		SNOMED CT
Code		DescriptionID (2576281011)
Active Ingredient [1]	Name	Fluticasone
	Strength Numerator Value	500
	Strength Numerator Unit	microgram
Active Ingredient [2]	Name	Salmeterol
	Strength Numerator Value	50
	Strength Numerator Unit	microgram
Dose Form		Nebuliser liquid
Dosage	Maximum Dose Value	1
	Dose Unit	Dose
Frequency		2 times in 1 day (twice a day)
Route of Administration		Inhalation
Start date		01/01/2005
Stop date		
Status		Ongoing
Medication reviewed		Yes
Source		Current CURe specialty area prescription (verified)

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V. DISCUSSION

A. Interoperability

The medication model presented caters for the major aspects of interoperability in terms of drug names, coding system and common dosage instructions. While in this model, active ingredient strength and dosage use a single unit, some specialties have indicated the need for multiple units, or conversion units, e.g. for inhaled steroids. References to standard conversions can be made available to users on the user interface, instead of representing them in the medication model.

B. Recording of unlicensed drugs

The medication information recorded concern prescribable licensed drugs. However, some domain experts have requested the recording of clinical trial drugs or unlicensed drugs. The medication model presented is not for an e-prescribing system. As such, it does not limit the recording of only licensed drugs. However, to differentiate between licensed and unlicensed drugs, the model could incorporate a data element to indicate this, hence preserving the meaning of the information recorded. Moreover, this requirement will impact on the standardised terminology for drugs and ensuring that both licensed and unlicensed drugs are present.

VI. CONCLUSIONS AND FUTURE WORK

In this paper, we presented a medication model to record the medication usage of patients in secondary care. The need for such a model arose from the lack of integration between healthcare systems, especially those developed for research. The medication model has been developed to allow patient medication information to be recorded and queried across multiple medical research specialty areas. Existing drug dictionaries and datasets have been developed mainly to standardise electronic prescription and medication order and management. We have adopted some of the relevant elements to develop a medication model to support secondary care research.

In future work, we will be investigating the categorisation of drugs by experts to facilitate the selection of drugs. This is aimed towards providing an agreed shortlist of medications based on each specialty area, or other grouping, such as inhalers, to enable users to select drugs from the shortlist rather from the list of all drugs. In the CURe application, we are also working on enabling users in different research specialty areas to view medications recorded across specialty areas, for the safety and care of the patients, while respecting the ethical and authorisation measures in place.

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