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Blendal, Rasmus Guldhammer; Pape-Haugaard, Louise

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An International Minimal Patient Care Report Exemplified in FHIR to Facilitate Standardisation and Interoperability of Emergency Medical Services Data

Rasmus Guldhammer Blendal, Louise Pape-Haugaard

Department of Health Science and Technology, Aalborg University, Aalborg, Denmark

Abstract

Lack of semantic interoperability is a common problem within healthcare IT. In prehospital sector it results in emergency medical service data being stuck in the emergency department, despite being important to clinicians outside the emergency department in treatment of the patient. Steps towards semantic interoperability within the prehospital area, on an international level, was taken by first creating an international common data set by use of two different national data sets and scientific literature. The usability of the created data set was showcased by example of a clinical case from emergency medicine. With common data elements established the next step was profiling the data set in FHIR, to further facilitate interoperability, as a common exchange standard is paramount for systems to interoperate.

Keywords:

Interoperability, Emergency Medical Services, Emergency Department, FHIR, Standardization.

Introduction

The idea of collecting patient data before patients reach the hospital, has been around for half a century in the US [1]. In 1966 a study investigated how lack of prehospital data could have an influence on hospital acquired mortality [1]. In 1995 consensus on a standardised comprehensive list of data points to be collected from trauma patients was reached. This standardised list of data points is the basis for the American National Emergency Medical Services Information Systems (NEMSIS), which is used across the US to store and standardise data collected by Emergency Medical Service (EMS) agencies. NEMSIS enables the possibility to check performance of clinical interventions in the prehospital field and conduct cohort studies [2]. However, in European eHealth consisting of different nations, different legislations, different vendors the requirements for prehospital data points have a high degree of variance and have created various data sets. A possible solution to proprietary data sets and lack of interoperability, is to standardise the data collected by EMS internationally along with the way the EMS data is exchanged internationally. A such solution was made by McClay et. Al. [3] called DEEDS, a purely US centric data set with 725 data

elements, included in the Health Level 7 (HL7) v3 specification. A study by Brammen et. Al. [4] compared the data elements in DEEDS with the German equivalent (GEDMR). The authors found significant differences between the two data sets in certain domains and their results support the development of an international standard for ED data elements [4]. An issue with DEEDS and GEDMR is the sheer size of the data sets which can limit adaptation, due to the work required to map the data elements to existing ones in the individual EHR systems. Additionally, DEEDS is part of the HL7 v3 specification, a very robust but ill-adopted standard due the extensive implementation work required, why it did not see much adoption worldwide compared to its predecessor. A solution to the issues with DEEDS and GEDMR is to create a minimal data set and use a specification that allows for simpler implementation. An emerging standard for sharing healthcare data across systems is the Fast Healthcare Interoperability Resources (FHIR) from HL7 [5]. FHIR enables standardisation of clinical data exchange, by allowing context to be kept, and terminology bound to the data [5, 6].

The objective in this study is to investigate how sharing of clinical meaningful minimal EMS data can be facilitated by the use of FHIR.

Materials and Methods

To investigate how sharing of clinical meaningful minimal EMS data can be facilitated by the use of FHIR we need to agree on a common international data set. Hence, the first step is to create such a data set. Further, we need to investigate how this data set can be profiled using FHIR. To profile in FHIR we have identified a clinical case.

The International Data set

The international data set consists of the intersection data points from two national standardised lists of data points. Variations between nations in collected data was expected, why the minimal data set will only cover the most clinically essential data for the emergency department (ED) to properly treat the patient. Examples of intersecting categories in EMS data are: Injury information [7], medical history [8], allergies [7], procedures performed [7], and patient physiology measures [9]. Additionally, information in relation to the

patient's symptoms/ immediate diagnosis and triage levels to determine the amount of personnel and resources required for the given patient [10]. The main requirements for a data element to be included in the minimal data set are: a) clinically essential, as previously defined, for the ED to understand the prehospital patients' situation, b) essential for the ED facilitate care of the patient. In this study, we deselect logistical and administrative data points.

Elements present in both EMS data sets but not fulfilling the clinical relevance requirements will not be used. When there is consensus on the category, but too little overlap between the data elements used to describe the category, literature will be used instead of the two national EMS data sets to find clinically relevant data elements.

Profiling the clinical case in FHIR

An international minimal data set for the prehospital sector, from here on referred to as IMPCR (International Minimal Patient Care Report), can only solve part of the problem described previously. The technical part of interoperability has to be solved using a standard exchange protocol fit for clinical data exchange. FHIR was chosen as the communication standard due its rapid adoption by vendors and an active community, making it a very promising standard that can see widespread use. Further, international projects have begun working towards international interoperability between EHR systems using FHIR, such as the Trillium project [11]. The clinical case chosen to be profiled in FHIR is presented in table 1.

Table 1- The clinical case has been adapted from [12]

Clinical case
The local EM services have been called to the local riding club to collect Kathrine Smith, a 24-year old woman who has fallen off her horse. Katherine is conscious but has pain in her pelvic area, she rates it an 8 out of 10. The EMS personnel notes that she has no known allergies and is an otherwise healthy young woman. Due to the height of the fall, horse was in mid jump, she is put in a hard collar and taped to the hard spine board to ensure spinal stability. Once in the ambulance her vitals are measured Temp: 36.2C, HR: 90/min, RR: 22/min, BP: 110/ 65 mmHg, SpO2: 98%OA and GCS 15. She is given a 50 mcg bolus of Fentanyl for the pain along with an additional 75 mcg via IV during the ambulance ride. The iliac crest feels tender when palpated. The EMS personnel suspects a pelvic fracture, performs a triage and transport her to the ED.

Results

The International Data set

The categories and data elements of IMPCR can be seen in Table 2. The four categories marked with an asterisk contains data elements from the literature. The injury category takes its elements from trauma registries in Europe and USA such

as [13, 14], to ensure data collected can be transferred to appropriate registries. Triage uses the Emergency Severity Index v4 as both national EMS data sets used a proprietary triage system, instead of developing a third triage system based upon the two, an internationally validated triage system was chosen [15, 16, 17]. Patient Assessment uses the ABCDE system which has widespread use and is recommended by the European Resuscitation Council [18, 19]. Cardiac arrest was another category where the two ePCRs differed, a report form with international backing and consensus from multiple cardiac societies was therefore chosen [20]. The remaining categories and data elements were found in the two EMS data sets.

Table 2 - Categories and data elements of the International Minimal Patient Care Report. The asterisk denotes the elements were found in the literature

International Minimal Patient Care Report (IMCPR)	
Patient	Name Gender DOB Identifier
Additional Patient Information	Allergy Severity Recent surgery/medical history Time of surgery/medical history
Medication	Active Ingredient Dosage Unit Dispensation
Cardiac Arrest*	<u>Cardiac arrest determined by:</u> Cause of arrest, Treatment before EMS arrival, Bystander CPR Defibrillation before EMS Resuscitation attempted by EMS Locations of arrest Witnessed Initial rhythm Chest impressions Ventilation <u>Time of:</u> collapse, call receipt, vehicle stopped, first rhythm analysis, death or cessation of CPR Spontaneous circulation on arrival
Injury*	Type Mechanisms Traffic factors
Diagnose/symptoms	Central Nervous System Respiratory System Musculoskeletal + Connective Tissue Circulatory System Abdomen Psychiatric/Mental/Behavioural Other Primary/action diagnosis
Patient assessment	Airways Breathing

	Circulation Disability Exposure
Procedures	Time of procedure Procedure performed Performed by
Vital signs	ECG (measurement, Type, interpretation) Systolic BP Diastolic BP Heart Rate SpO ₂ Respiration Rate ETCO ₂ Blood Glucose Level GCS total + Sub scores Pain Scale Body Temperature
Triage	Requires immediate lifesaving intervention? High risk situation? Confused/lethargic/disoriented? Severe pain/distress? How many different resources are needed? Danger zone vitals? ESI Score

Profiling the clinical case in FHIR

Patient: Allergy information was profiled in the same way as medical history, with one code/value indicating "No known allergies", since the patient had no allergies. The profiled Patient was very similar to the base resource, as only animal and multipleBirths had their cardinality set to 0..0 as these elements are never relevant, while gender and DOB had their cardinality set to 1..1 to emphasise their importance.

Medication: To profile Medication, MedicationAdministration was chosen, as this resource specifies what, how, and by whom medication was administered. Few FHIR elements had their cardinality set to 0..0. The elements with their cardinality set to 0..0 were: 'notGiven', 'reasonNotGiven', 'prescription', 'device', and 'eventHistory'. These were removed because they are not needed for the prehospital use-case. The prescription covers "the original request/instruction or authority to perform the administration", which is not relevant for EM services, as EMS personnel are usually not allowed to administer medication not within their authority, why performer will be sufficient to track who administered the medication.

Injury: Injury was profiled using the Condition resource, as the injury itself has a direct impact on the patient's health. Specifying the type of injury and the mechanisms behind it, gives insight into the patient's condition and the required resources needed to treat the patient in the ED. Only two elements in Condition are required to capture the injury information from the clinical case, why rest of the elements are left as is. Both 'category' used to specify the type of injury and 'code' used to specify the mechanism behind the injury

are sliced, instead of using valuesets. Slicing was used to illustrate what the valueset should contain, each slice holds a SNOMEDCT value, that has been chosen without further thought, as they are strictly example codes.

Diagnosis/Symptoms: Diagnose/Symptoms was modelled in FHIR using Condition. The main elements used in the resource are 'category', 'severity' and 'code'. category should ideally contain a valueset which holds the data elements of Diagnose/Symptoms e.g. Central Nervous System and Respiratory System. code should ideally be a valueset for the chosen category e.g. for respiratory system it could be: Pneumonia, Pneumothorax. The primary diagnosis can be noted in severity.

Vital signs: All measurements but ETCO₂ and blood glucose were existing profiles found at <https://registry.fhir.org/>. ETCO₂ and blood glucose were profiled by copying a heart rate profile and changing the 'names' and 'code'. Glasgow Coma Scale was profiled by having the total score as the value of the observation and the three sub scores as components of the total value.

Triage: The ESI Triage model can be seen as a questionnaire with a series of yes/no question and a resulting score. The questionnaire was profiled using the questionnaire resource by slicing 'item' and creating one less number of slices than number of questions. Because question A: Requires immediate lifesaving intervention? is contained in the outermost item and therefore not part of the slices. Next, each question had the answer set linked to an existing valueset if possible, valuesets for Yes/No did exist. In the case the answer set did not exist as a valueset the answer element was sliced to contain the custom answers (e.g: None/One/Many).

Procedure: Procedure was modelled using Procedure, as it seemed the obvious choice. The procedure, which should contain a valueset of possible procedures, was modelled to 'code' in the resource, with four example procedures as slices. The profile is able to store the expertise level of the performer such as: basic life support, advanced life support or physician. Information that might be recorded automatically system side.

The clinical case is modelled in FHIR and presented in Table 3.

Tabel 3- Illustrates how the clinical case is modelled in FHIR

Clinical Case	IMPCR Category	FHIR Resource(s)
...Kathrine Smith, a 24-year old woman The EMS personnel notes that she has no known allergies and is an otherwise healthy young woman	Patient + Additional patient information	Patient, AllergyIntolerance, Observation

..fallen off her horse...horse was in mid jump..	Injury	Observation
..is conscious but has pain in her pelvic area, she rates it an 8 out of 10.	Vital signs + Diagnose/symptoms	Observation.Vitalsigns
...put in a hard collar and taped to the hard spine board to ensure spinal stability. . .	Procedure	Procedure
Once in the ambulance her vitals are measured Temp: 36.2C, HR: 90/min, RR: 22/min, BP: 110/65 mmHg, SpO2: 98%OA and GCS 15	Vital signs	Observation.Vitalsigns
She is given a 50 mcg bolus of Fentanyl for the pain along with an additional 75 mcg via IV during the ambulance ride	Medication	MedicationAdministration
The iliac crest feels tender when palpated. The EMS personnel suspects a pelvic fracture...	Diagnose/symptoms	Condition
..Performs a triage..	Triage	Questionnaire

Discussion

The International Data set

The national EMS data set in USA and a small European country have been chosen due to the difference between the two countries healthcare systems, insurance/publicly funded vs entirely publicly funded respectively. The choice of using national EMS data sets from different healthcare systems will increase the likelihood of identifying the relevant data points to include in the new minimal data set, as the EMS data sets are expected to vary more than that of two homogeneous healthcare systems. As the aim of the data set was to be minimal, coarser granularity were used when possible, to reduce the amount of data points. The benefit of an intermediate level of granularity is faster data retrieval for the clinician, as they try to get an overview of the patient [21]. An example of this is the disease/diagnose category, where the intended value sets, based on the two national data sets, are the most common diseases/symptoms encountered in the prehospital sector split into organ systems. An alternative design would

be to register the overall category, then the exact anatomical location and then the symptom. Instead the coarser version was chosen, where the diagnosis is registered to reduce the data point having to be collected. Location of the disease/symptom can in some instances also be inferred based upon the organ system and diagnose/symptom chosen.

Two national data sets and literature was used to create IMPCR, a data set containing clinical data elements able to describe the prehospital patient and their situation. IMPCR is mostly based on the two data sets, as it gave a solid departure point for identifying the required clinical categories. If consensus on data elements can be found between two data sets independently developed, the element must have clinical relevance. An additional data set could have been added, it might have had the benefit of settling disagreements, further confirming consensus, or in the worst case added further disagreement. In case of more disagreement more literature would have been used if possible. As this clinical data sets builds upon existing data sets and aggregates clinical report forms from different clinical specialities, it does not follow the usual method of developing a clinical data set, it builds upon existing work instead of starting from scratch. This is an advantage because the data sets are already being used, thus have a proven track record of being able to provide the adequate information to clinicians in the ED. The addition of validated report forms from clinical societies, results in further standardisation of how clinical data is reported and can ideally support research in addition to the clinical use case. Other data sets have been created or revised using systematic literature reviews, expert opinion and consensus found via techniques such as 'Nominal Group Technique' [13, 22].

IMPCR's capabilities were tested using a realistic clinical case, see table 6.1, where the clinical case was split into its components and matched with the appropriate IMPCR category. IMPCR was able to capture the relevant data from the clinical case satisfactorily, however more cases, especially complicated ones, should be tried in the future. IMPCR is capable of capturing data meant for the clinic and by being a standardised data set, it enables comparison of emergency departments and emergency medical services both nationally and internationally. Using identical data sets allows for comparison because the data elements are directly comparable opposed to having to map from one data set to another or pick out a few characteristics [23] - which can bring benefit for research and quality control purposes. But having been creating with minimalism in mind, there is a risk it is not entirely suitable for research at a later time, this could be both due to granularity of the data or optionality. There is a risk of incomplete data when certain elements might not get collected if they are not applicable to the patient in question [24]. A potential issue that can be solved by removing optionality and requiring negative values when the category/element is not relevant. The current version of IMPCR additionally lacks terminology binding to properly facilitate semantic interoperability. Terminology binding is crucial as it keeps the semantic meaning of data instead of leaving it as an arbitrary value. Further it combines the multiple ways of describing a single medical concept into one, allowing systems not using the same data set, to understand what they

receive so long as they can look up the terminology. [25, 26, 27].

Flexibility of FHIR

FHIR being based on base resources that can satisfy a range of use-cases, can result in model variability and multiple right ways to model. An example of this was encountered when profiling medical history, there was a choice whether it should have been profiled as an Observation or a Condition, as both are able to hold the required data. Either choice can therefore work depending on the light in which the prior medical issues are viewed: as potential problems that will require additional medical attention, or as 'need to know' information for the emergency personnel. This way of having multiple ways of describing/modelling the same thing is possible because FHIR follows no standard model, opposed to more rigid standards such as HL7v3 which used the RIM [28]. The flexibility of FHIR means it alone is not sufficient to facilitate semantic interoperability, as there is a risk of independent project/vendors developing differing proprietary profiles for the same use-case, thus contributing to fragmentation and interoperability issues within the healthcare sector [29, 30].

As a response to this concern the SMART team [30], put forth a small set of profiles where they specify terminologies, element cardinality and type choice to ensure apps created with SMART, could semantically interoperate. Likewise, a larger scale project, Argonaut, now collaborating with SMART, has gathered traction [31, 32]. Argonaut is a collaboration between private vendors, such as Cerner and Epic, that are "Creating open industry Implementation Guides in high priority use cases of importance to patients, providers and the industry as a whole" [31], a project that is open to other organisations to foster interoperability [32]. Reusing profiles and sharing implementation guides in FHIR is best practice, to ensure widespread support of commonly used profiles, but this can result in first movers dictating the profiles. There is the risk of using sup-optimal profiles for the given resources, as first movers can create a tradition, and effectively take over the market. While interoperability is the goal of FHIR, an interesting discussion arises: On whose terms, should the goal be reached?

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Address for correspondence

Rasmus Guldhammer Blendal - rasmusblendal@hotmail.com