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Integrating Laboratory Testing Results at Point-of-Care in Hospital@Home Care Settings: A FHIR-Based Approach

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Abstract. The care model Hospital@Home offers hospital-level treatment at home, aiming to alleviate hospital strain and enhance patient comfort. Despite its potential, integrating digital health solutions into this care model still remains limited. This paper proposes a concept for integrating laboratory testing at the Point of Care (POC) into Hospital@Home models to improve efficiency and interoperability. *Methods:* Using the HL7 FHIR standard and cloud infrastructure, we developed a concept for direct transmission of laboratory data collected at POC. Requirements were derived from literature and discussions with a POC testing device producer. An architecture for data exchange was developed based on these requirements. *Results*: Our concept enables access to laboratory data collected at POC, facilitating efficient data transfer and enhancing interoperability. A hypothetical scenario demonstrates the concept's feasibility and benefits, showcasing improved patient care and streamlined processes in Hospital@Home settings. *Conclusions:* Integration of POC data into Hospital@Home models using the HL7 FHIR standard and cloud infrastructure offers potential to enhance patient care and streamline processes. Addressing challenges such as data security and privacy is crucial for its successful implementation into practice.

Keywords. Cloud solutions, FHIR, Hospital@Home, Interoperability, Point-of-Care testing

1. Introduction

Hospital@Home is a care model whereby patients who would normally be treated in hospital are cared for and managed at home [1]. Individual implementations of this care model may vary slightly, but the core of the model is always similar, e.g. there is a hospital involved at least to a certain extent which is in contrast to Care@Home care models where family doctors or other ambulatory care providers are in charge of coordinating the care. The severity of the patient's condition must allow for treating them at home, where they are cared for by nursing staff and medical services including 24-hour access to telemedicine. Home visits by specialist staff can include a range of examinations and diagnostic tests, such as vital signs, blood tests, electrocardiogram or ultrasound [2]. The objective behind this care model is to relieve the pressure on hospital structures and to offer patients who are eligible for Hospital@Home more comfort and privacy in their own environment. Some benefits of this model include a reduction in the risk of infection and falls, as well as an improvement in the quality of care and the

overuse of medication [2]. Recent research found that integration of digital health solutions into Hospital@Home care models is still limited [3] although these technologies promise to support continuous monitoring of vital parameters and other parameters at home or can even deliver treatment. Most available studies on Hospital@Home have been conducted when digital health solutions and point-of-care testing (POCT) were not yet available [4]. Currently, the POCT market is "projected to grow at a compound annual growth rate of 6.1% from 2024 to 2030" [5]. POCT refers to laboratory testing performed directly at the point of care. Laboratory results are generated directly on the ward or in the operating theatre of a hospital, in a doctor's surgery, in emergency situations, in a pharmacy, or in the patient's home. Tests that patients perform themselves, such as pregnancy tests or independent blood glucose monitoring for diabetes mellitus, are also called POC measurements [6].

The aim of this paper is to develop, within the framework of a Hospital@Home model, a possible concept that describes how the data is transferred between the measurements taken at home and the hospital. Specifically, we are addressing the questions of how data can be retrieved by healthcare providers immediately after the measurements have been conducted at home and how the data can be accessed from a hospital for continuous monitoring.

2. Method

To develop the concept, we first collected requirements and defined a scenario. Specifically, we collected information on which data that is often measured as part of Hospital@Home care models. We identified five different groups: vital parameters (pulse, blood pressure etc.), blood glucose, laboratory values, ECG and ultrasound. Given the increase of diabetes in the population, we focused on measuring vital parameters and blood glucose within our concept. As a concrete POCT device, we considered cobas® Pulse from Roche Diagnostics. However, we developed an architecture for accessing data collected by POCT devices in general from a clinical information system or other frontends. Our concept bases upon HL7 FHIR R4 (http://hl7.org/fhir/), a standard developed by Health Level Seven International (HL7). HL7 FHIR is based on web technologies such as the programming interface RESTful APIs and the data formats JSON and XML. The modular structure allows resources to be used and combined individually, providing flexibility and adaptability. HL7 FHIR facilitates the handling of different types of healthcare data, from patient information to laboratory results. Central to HL7 FHIR are the standardized data models that provide clear structures for the representation of health information, which improves interoperability between different healthcare systems and applications.

3. Results

This section first describes the envisioned scenario for Hospital@Home and then outlines our architecture for integrating POCT devices.

3.1. Scenario

Nurse Svenja and a physician visit Mr. Pfister at home for a routine check-up as part of a Hospital@Home care model. The doctor conducts a physical examination, using a mobile ultrasound machine and listening to his lungs, and recommends that the prescribed treatment be continued. Svenja gives Mr. Pfister an antibiotic infusion and checks his vital signs using a POCT device for measuring temperature, blood pressure, pulse and blood glucose. She also uses the device's camera to photograph and monitor a wound. The data is immediately transmitted to a cloud server as soon as an internet connection is available. Svenja can access the data together with previous measurements through her tablet application that retrieves the data from the cloud server. The tablet application allows also to retrieve relevant data from Mr. Pfister's medical records stored in the hospital information system. The technology used ensures efficient and informed care. For healthcare professionals, the system minimizes post-visit documentation. Vital signs and other relevant data resulting from the POCT are automatically retrieved from the cloud server, and the mobile device facilitates on-site care without worrying about internet connectivity. Interdisciplinary coordination is improved due to the data access for all persons involved in the treatment, allowing immediate adjustments to care plans based on real-time data.

3.2. Architecture and HL7 FHIR resources

Our architecture for integrating POCT into Hospital@Home care processes comprises POCT devices, a cloud server and applications such as a tablet application that visualizes the data (see scenario) or a clinical information system that retrieves the data for storing in the medical record of a corresponding patient. Within our concept, we decided for a cloud server to store the data since it offers the possibility to access data quickly and anywhere as long as there is an internet connection.
The general process is as follows: Data from a POCT device is directly converted into HL7 FHIR format after measurements have been conducted, transferred via a cloud gateway and then stored in a cloud service. Once it is stored in the cloud, it can be retrieved upon request through cloud gateways. All data is automatically assigned to a case that belongs to a patient: the 'Encounter' resource of HL7 FHIR is used. Each patient is modeled as a HL7 FHIR 'Patient' resource. By this, all data generated from an examination is directly assigned to a specific (patient) case. The value measured by POCT devices are modelled as 'Observation' resource. Several 'Observation' are aggregated in a HL7 FHIR resource 'DiagnosticReport' (see Figure 1).

4. Discussion

In this paper, we described an approach to integrate POCT devices into the system landscape of Hospital@Home using HL7 FHIR and a cloud server. In Hospital@Home care models multiple stakeholders may be involved (e.g. nurses, physiotherapist, hospital, family doctor etc.) who use their own information systems. Our approach ensures that the data collected at home can be integrated in such systems. The synergy of cloud computing and HL7 FHIR format is pivotal for healthcare's future, providing the infrastructure to support HL7 FHIR while improving flexibility, scalability, and interoperability as well as enhancing information exchange [11]. The architecture itself

was not yet implemented. Only a front-end to visualize the data collected by the POCT device was implemented.


```
{
 "resourceType": "DiagnosticReport",
 "status": "final",
 "code": {
  "coding": [
   {
    "system": "http://loinc.org",
    "code": "2339-0",
    "display": "Glucose [Mass/volume] in Blood"
   }
  ],
  "text": " Glucose [Mass/volume] in Blood "
 },
 "subject": {
  "reference": "Patient/123",
  "type": "Patient"
 },
 "encounter": {
  "reference": "Encounter/encounter-001"
 },
 "effectiveDateTime": "2024-03-04T15:43:00+01:00",
 "result": [
  {
   "reference": "Observation/001",
   "type": "Observation"
  },
  {
   "reference": "Observation/002",
   "type": "Observation"
  }
 ]
}
```


Figure 1: Example in HL7 FHIR for a DiagnosticReport on a glucose in blood with two observations shown in json-Format

In today's digital age, the use of cloud solutions has become a fundamental component for companies of all sizes that want to increase their efficiency and work more flexibly [8]. Cloud storage offers advantages like scalability, flexibility, and improved accessibility, allowing companies to use fewer physical storage devices and enabling easy data access from various locations, enhancing employee collaboration and mobility [9]. They are also cost-efficient, reducing the need for extensive on-site IT infrastructure and personnel for IT system maintenance, as these tasks are handled by cloud providers [10]. However, the concrete benefits in the use case described in this paper still has to be assessed together with the acceptance of a cloud-based solution. A recent paper concluded that security and privacy in cloud environments in healthcare still need to be aligned and considered [11]. This is a relevant factor for acceptance of a cloud -based solution in healthcare. Additionally, compliance of our approach with healthcare regulations such as HIPAA in the U.S. still has to be assessed. Security measures such as encryption and robust authentication mechanisms are critical to be implemented and remained unconsidered in this concept yet.

The suggested cloud service could be replaced by a personal health record, with the data collected at the POC stored in the record in FHIR format. In several countries such personal health records are already in place. The Dutch personal health record for example specifies already a scenario in which a patient uses his Personal Health Record to collect vital data and blood glucose test values from devices and sends these to the care professional, who accepts the incoming values – the data is exchanged in HL7/FHIR (https://informatiestandaarden.nictiz.nl/wiki/MedMij:V2020.01/FHIR_VitalSigns).

Converting data directly into HL7 FHIR format at the POCT device is an efficient approach. It ensures efficient transmission as the data is already in the desired format and can therefore be transmitted more quickly [12]. However, this approach requires that the POCT devices have the necessary computing resources and software capabilities for this conversion. It remains open for future research to assess whether all POCT devices can support this feature. As POCT devices can generate significant amounts of data, performance issues can arise when managing, storing and querying these data on the cloud server. In summary, our concept aims to provide a solution to share data collected in a Hospital@Home care setting with healthcare provider, in particular to store the collected data in information systems at provider side (e.g. clinical or practice information system). This allows for a continuous progress monitoring at the provider's side and can help in supporting patient safety in Hospital@Home care settings. In future work, we want to study whether mHealth apps or data from wearables could be connected in a similar manner. Since these devices generate even more data than POCT devices, data aggregation would have to be conducted.

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