Localisation, Personalisation and Delivery of Best Practice Guidelines on an Integrated Care and Cure Cloud Architecture: The C3-Cloud Approach to Managing Multimorbidity

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Abstract. *Background*: C3-Cloud is an integrated care ICT infrastructure offering seamless patient-centered approach to managing multimorbidity, deployed in three European pilot sites. *Challenge:* The digital delivery of best practice guidelines unified for multimorbidity, customized to local practice, offering the capability to improve patient personalization and benefit. *Method:* C3-Cloud has adopted a co-production approach to developing unified multimorbidity guidelines, by collating and reconciling best practice guidelines for each condition. Clinical and technical teams at pilot sites and the C3-Cloud consortium worked in tandem to create the specification and technical implementation. *Results:* C3-Cloud offers CDSS for diabetes, renal failure, depression and congenital heart failure, with over 300 rules

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and checks that deliver four best practice guidelines in parallel, customized for each pilot site. *Conclusions:* The process provided a traceable, maintainable and audited digitally delivered collated and reconciled guidelines.

Keywords. multimorbidity, integrated care, clinical interpretable guidelines, co-production, clinical decision support

1. Introduction

There is an increasing need to organize care around the patient and not on conditions [1], taking into account his or her multiple physical and psychosocial conditions [2]. An integrated, patient-centered care and cure delivery architecture needs to be developed considering the realities of multi-morbidity and poly-pharmacy. This needs to take into account the medical, technological, organizational and socio-economic challenges of creating a collaboration environment for all of the stakeholders involved in the holistic continuum of care. Clinical guidelines re-factor the best available published evidence on clinical effectiveness, into decision trees and care pathways. They are increasingly multi-professional, and work across care providers. However, they usually focus on treating a single disease. Clinical guidelines may clash (e.g., due to incompatible treatment and monitoring regimes). Following more than one clinical guideline, can result in inefficiencies for the patient and for the health system, due to duplicating and inconveniently scheduled investigations and clinic visits, and more importantly, treatments that may exacerbate another condition [3].

C3-Cloud is ICT infrastructure enabling a collaborative care and cure cloud for continuous coordination of patient-centered care activities; by a Multidisciplinary care Team (MDT), and patients/informal caregivers. It implements integrated care pathways for chronic heart failure, renal failure, depression and diabetes, based on best practice guidelines [4]. The C3-Cloud approach to integrated care is demonstrated in varying clinical, technological and organizational settings by piloting in three European regions (South Warwickshire, Basque Country, and Region Jämtland Härjedalen) with considerably different health and social care systems, and ICT landscapes.

The paper presents the co-production, and implementation approach adopted in C3-Cloud, which delivers an infrastructure able to offer multiple personalize-able best practice guidelines for multimorbidity. C3-Cloud also incorporates localization, necessary to be deployed in the heterogeneous pilot site environments.

2. The Collaborative Care and Cure (C3-Cloud) Solution to Multimorbidity

C3-Cloud achieves its objectives using the concept of the personalized care plan. The care plan consolidates and reconciles data, goals, treatment, and medications, personalized for each patient, addressing their collective multimorbidity needs, and encapsulating clinical practice guidelines. The care plan can be thought of as an integrated care visualization and management tool. Figure 1 presents the high-level architecture of C3-Cloud and its constituent components, which offer the care plan. The Coordinated Care & Cure Delivery Platform (C3DP) is an innovative online means for multidisciplinary care team members (MDT) to collaboratively manage (execute, monitor, update) the integrated personalized care plans for patients with multi-morbid

conditions. Clinical Decision Support Services (CDSS) support personalized care plan development and execution by clinical guideline reconciliation, risk stratification, poly-pharmacy management, and goal setting and monitoring. A Patient Empowerment Platform (PEP) ensures active participation of patients and their informal caregivers to the management of their multi-morbid chronic conditions, thus alleviating the non-adherence problem. Interoperability middleware addresses technical (TIS), semantic (SIS), and privacy/security (SPS) interoperability challenges to seamlessly integrate with the existing health care, social care, and home/community care information systems. This will allow interfacing the information exchanges, but also the clinical terminology systems between the local systems and C3-Cloud.
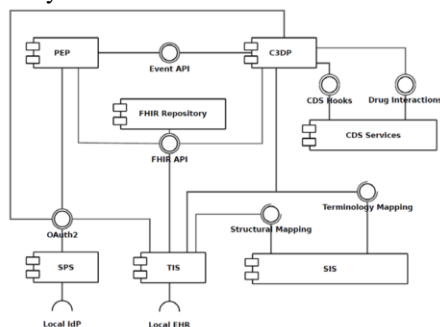

Figure 1: Overview of the C3-Cloud Architectural Components

Finally, all data are stored in a database as HL7 Fast Healthcare Interoperability Resources (FHIR) (https://www.hl7.org/fhir/), annotated with the codes of the terminology systems, C3-Cloud uses. FHIR, along with other standards used internally in C3-Cloud, result in an easily maintainable and upgradeable architecture.

3. From Medical Knowledge to Localization and Personalization

One of the main objectives of C3-Cloud is to deliver integrated care, based on best practice guidelines. In order to achieve this, C3-Cloud had to overcome a number of challenges: a) unify and reconcile guidelines to offer the patient a single multimorbidity management plan rather than a digitization of multiple separate guidelines; b) deliver an infrastructure suitable to customize the vision of an enhanced service for all pilot sites; and c) increase patient benefit by offering further personalization options based on what the clinical team of each pilot site identified as important. Figure 2 illustrates a process that enabled co-production of the consolidated and reconciled multimorbidity guidelines delivered by C3-Cloud. Local practice for each pilot site was identified by the clinical teams of each pilot site. Then, pilot sites recorded their vision of an enhanced service, and performed a gap analysis with the current service to identify core functional requirements for C3-Cloud. This includes personalization rules that need to be applied in multimorbidity, which are then translated into service processes. For example, online messaging to adjust goals of a patient, and online patient reported outcomes triggering automated clinical recommendations.
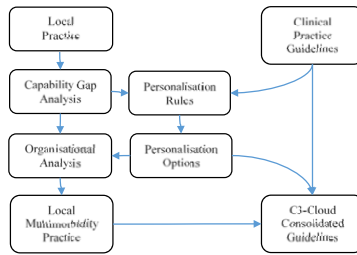
Figure 2: C3-Cloud Consolidated Multimorbidity Guidelines Process

An organizational analysis was then performed to identify how the newly defined capability would be integrated to each pilot site, including allocation of roles, and specification of local procedures. Figure 3 illustrates a comparison of how the C3-Cloud enabled service would fare against existing practice, as evaluated by clinical teams in each pilot site. The evaluation dimensions were identified by the C3-Cloud consortium based on current literature on integrated care. This process was informed by the UK National Institute of Care Excellence (NICE) evidence-based guidelines, which provided a skeleton gold standard that all pilot sites used as reference. NICE guidelines balance best available evidence with cost benefit, ultimately resulting in a gold standard for care. Nevertheless, even the NICE guidelines, offer limited supported to multimorbidity.


Figure 3: Before and after pilot site internal clinical evaluation of the service

Multimorbidity options, rules and actions, were developed by the C3-Cloud Clinical Reference Group (CRG), consisting of clinicians from each pilot site. The CRG also had overall oversight of the resultant clinical practice. Throughout this process, functional and technical requirements for C3-Cloud were also identified by using a Model-Driven Engineering approach, which resulted in the specification of the software architecture, as well as the system specification document.

4. Implementation of Guidelines in C3-Cloud

The specification of the C3-Cloud guidelines was followed by their implementation, and deployment as part of the system. The guidelines development process resulted in a number of technical requirements for C3-Cloud. They provided requirements such as: data that needed to be stored in the FHIR database; the user interface that users (MDTs and patients) would experience, capturing all aspects of multimorbidity management identified in the guidelines; and automated rules implemented by the clinical decision

support modules. Figure 4 presents the steps followed for implementation of the CDSS logic, and integration with the local sites.
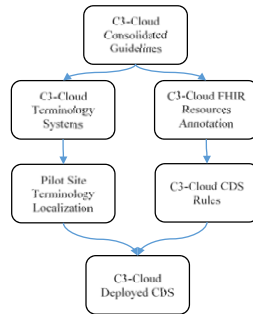
Figure 4: Guidelines Implementation and Deployment in C3-Cloud

In order to meet the interoperability requirements, each step of the C3-Cloud guidelines was annotated with terminologies by the CRG. This allows for unambiguous retrieval of the relevant information from the FHIR repository, as well as an automated interface, which mapped the C3-Cloud terms to the terms used in each pilot site. Furthermore, the guidelines were annotated with the FHIR resources with which they needed to interact. For example, when patients enter data, the system will create an [Observation] FHIR resource, and when the CDSS identifies suitable conditions for certain medications (e.g. beta blockers for high blood pressure), the system will propose to a physician new medication, by creating a [MedicationRequest] resource that they will need to review before approving. This resulted in an annotated logic of the guidelines, that was then implemented using the GDL2 openEMR standard [5]. The GDL2 implementation is deployed as an executable CDSS module, in each pilot site.

5. Conclusions

C3-Cloud had deployed collated and reconciled guidelines on multimorbidity in three European pilot sites. Achieving this required a co-production process involving the pilot site clinical teams, the C3-Cloud clinical reference group, the pilot site technical teams, and the C3-Cloud technical team. The process resulted in over 60 clinical scenarios, 300 CDS rules and over 380 design requirements.

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