An Integrated Solution for Sustainable Care for Multimorbid Elderly Patients with Dementia

WP3: Foundation of the Clinical Decision Support Services for the Management of Multimorbid Elderly Patients with Dementia

D3.1: A Computer Interpretable Guidelines Specification of the Complete CAREPATH Decision Support Logic

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Executive Summary

The report identifies the process followed by T3.1 that will contribute to the “Foundations of the Clinical Decision Support Services for the management of multimorbid elderly patients with dementia”. Task 3.1 defines the “Patient-oriented Computer Interpretable Clinical guideline modelling”. The main objective of WP3 is to establish the foundations of the Clinical Decision Support tools to be employed in CAREPATH, based on the consolidated guidelines recommended by WP6. This first release of D3.1 covers the methodology for modelling clinical practice guidelines, an overview of the clinical decision support service architecture, and how the clinical decision support services will be specified.

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Abbreviations

CAREPATH	An Integrated Solution for Sustainable Care for Multimorbid Elderly Patients with Dementia
CDS	Clinical Decision Support
CIG	Computer Interpretable Guideline
CPG	Clinical Practice Guideline
CRG	Clinical Reference Group
EHR	Electronic Health Record
FHIR	Role Based Access Control
HTTP	Hyper Text Transfer Protocol
ICD	International Classification of Diseases
M1/M12	Project Month 1 / Month 12
PEP	Patient Empowerment Platform
RBAC	Role Based Access Control
UML	Unified Modelling Language
WP	Work Package

1. Introduction

1.1 Document Scope

The goal of Task 3.1 'Patient-oriented Computer Interpretable Clinical guideline modelling (M1-M12)' is to model clinical practice guidelines so they can be executed as computer interpretable guidelines, to guide clinical decision-making based on evidence-based guidelines. Figure 1 shows the overview for Task 3.1 and its dependencies on other work packages in the CAREPATH project.

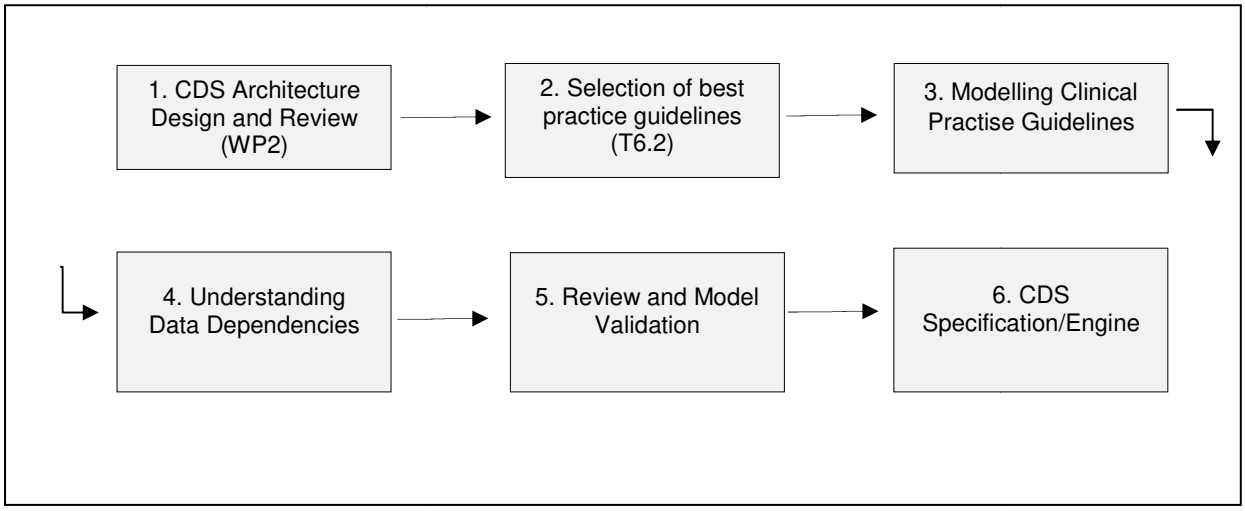

Figure 1: Overview of Task 3.1 and Dependencies

WP2 focuses on specification of the overall architecture, including the Clinical Decision Support (CDS) module, and how it will interact with the rest of the CAREPATH infrastructure (see D2.1, D2.2 and D2.3). This includes specification of the module level functionality, test cases, input, outputs, as well as the technical interfaces. The latter includes the standards and technology used, as well as how it will be configured specifically for CAREPATH.

In the case of computer interpretable guidelines (CIG), this includes how the CIGs will be communicated with the rest of the modules (output), including the API for data that CIG will need (input). This affects the work in T3.1 as the task will annotate the guideline models with elements of these specifications. For example, the modelled guidelines will be annotated using semantic interoperability standards (e.g., ICD-10 codes) to avoid ambiguity on clinical terms. Examples of other such standards include the FHIR resources from which information will be retrieved, and the CDS-hooks cards [1] that will be produced at each step of the guideline algorithm.

Task 6.2 is the task that will identify the best practice guidelines that will be adapted and modelled into the CAREPATH guidelines, from the review of relevant guidelines identified in D6.1. The task will integrate relevant guidelines, reconciling potential conflicts, resulting in the CAREPATH integrated guidelines. Task 3.1 will then unpack the decision making in the CAREPATH integrated guidelines and will model them as algorithms using flowcharts and activity diagrams. This will explicitly model every decision and path a patient may follow during their care. Where the guidelines are not clear, input will be elicited from the CAREPATH Clinical Reference Group (CRG) in WP6. If the pilot sites have identified aspects that will need to be implemented differently in their local setting, these will be recorded as localizations. Use of the model-based approaches will enable clear and traceable documentation of these variations.

Following specification of the decision-making logic, the task will annotate parts of the models with terminological codes for medical concepts, medications, as well as the FHIR resources [2] from which the data will be taken. This will allow unambiguous specification of what concepts the guidelines refer to, and which data elements correspond to each decision. This is a key step, as the models created will be in a form that is appropriate for review and validation by the CRG. Additionally, by identifying the data elements that will be needed from the FHIR repository, the task will also provide early specification of the requirements on

pilot sites, with regards to integrating their Electronic Health Records with the CAREPATH FHIR repository, de-risking the deployment task (Task 4.8).

The guideline models will be reviewed and validated by the CRG and clinicians at the pilot sites (according to the integration protocol of each site).

Finally, the annotated CAREPATH guideline models will be used by Task 3.4 for definition with CDS Hooks specification and by Task 4.5 for implementation as executables in the CDSS engine. Task 3.1 is crucial to the verification and validation of the CDSS, as the models that will be produced will be the link between the validation offered by the CRG, and the requirements provided to the CDS technical team. All rules, decisions, and algorithms in the models should be fully traceable to the code in the implementation. The model specification can therefore act as the requirements for the CDSS. Hence, the technical teams can verify that their implementation is what was specified in the models to a very high degree of confidence. Furthermore, the models are to be reviewed and approved by the CRG, hence, offering high degree of confidence in its validity. This is enabled by the increased comprehensibility of models, as they break down and visualize information that may be difficult to review as text, which could result in ambiguities.

1.2 Document Structure

The deliverable is organised as follows:

- Section 1 describes the scope of the task and document.
- Section 2 describes how the best practice guidelines and consolidated guidelines are selected and developed in CAREPATH.
- Section 3 describes the methodology for modelling clinical practice guidelines.
- Section 4 describes how the clinical guidelines are specified as CDS Hooks.
- Section 5 describes the process of review and validation of the models developed.
- Section 6 concludes the first release of the deliverable.

1.3 Clinical Decision Support System (CDSS)

Clinical Decision Support Systems (CDSS) provide decision support aids offering treatment suggestions, carry out risk assessments and provide guidance about polypharmacy management as well as being utilized by AICP during the creation and update of care plans. The CDSS also includes an Early Warning System (EWS), utilising algorithms built using machine learning techniques to identify potentially preventable situations.

- **Suggestion for Clinical Guidelines:** In CAREPATH, we will build clinical decision support services to deliver personalized guidance to healthcare professionals about the goals and interventions (treatment actions, patient monitoring activities and lifestyle management activities) that can be put into the active care plan of the patient. These suggestions will be built upon the recommendations of the clinical guidelines to achieve patient-centred and customised care. The exact content of Clinical Decision Support Systems (CDSS) to be implemented in CAREPATH depends on the output of Task 6.2 in which a holistic patient centred CAREPATH best practice guideline will be established. Task 3.1 will deliver the rules that will be implemented as clinical decision support services based on the holistic clinical guideline flow. The architectural design of the CDSS for clinical guideline suggestions, from a technical perspective is defined in D2.3 Section 3.3.4.

2. Definition of CAREPATH Guideline

Candidate guidelines have been identified in D6.1, such as guidelines for frailty, which will be reviewed and cross referenced against current practice at pilot sites. Additional guidelines will also be considered for example, the guidance using concept of intrinsic capacity. Task 6.2 is assessing the guidelines identified in D6.1 to create a consensus guideline for the project, also taking into account local variations at the sites. The second release of this deliverable (M12) will model these guidelines after these have been defined in Task 6.2.

Review of the formalised guidelines will be carried by the CRG, liaising with local clinicians where applicable. Identification of variation in terms of process, clinical decision making, as well as representation and use of semantic interoperability concepts will be modelled. The task will receive the consolidated guidelines from WP6, which will represent best practice. Task 3.1 will transform the clinical guidelines into models amenable to ICT software execution. The task will employ state of the art Computer Interpretable Guideline practice, to model the flow, information dependencies, as well as decisions that need to be made by the software. The logic of the guidelines will also identify the information, which when implemented will result in patient-centred and customised care. The task will also enrich the decision-making based on clinical guidelines, with information that will be collected by the Patient Empowerment Platform as well as the Home Monitoring Platform. With input from WP6 the task will develop a specification of how passively collected data can satisfy the various conditions of decision-making, allowing the pathways to automatically progress using the collected data, and offer recommendations. The task will also identify the data types missing to make decisions in line with the guidelines, and review with WP6 how actively collected data such as patient reported outcomes can be used to fill the gap and result in decisions. As part of this, Task 3.1 will liaise with the Clinical Reference Group (CRG) and WP2 to evaluate whether data collection is compliant with the project data handling objectives. These specifications will be implemented within the scope of Task 4.5.

3. Modelling Clinical Practice Guidelines

This deliverable will be updated with Flow Charts and Activity Diagram from the Interim M8 Release through to the M12 Final release. Semantic interoperability (coding) allocation, and review by clinicians' disambiguation of concepts and assignments of codes will be considered. This will be performed by the clinical reference group. Rules are to be documented with a constrained language based prepositional logic e.g., "blood pressure (SNOMED code) AND higher than previous 3 measurements" will trigger an action.

3.1 What is a UML Activity Diagram?

The Unified Modelling Language (UML) is general-purpose modelling language [3]. UML Diagrams can be grouped into two main types, structural and behavioural, as seen in Figure 3.

An activity diagram visually presents a series of actions or flow of control in a system like a flowchart or a data flow diagram. Activity diagrams are often used in business process modelling. They can also describe the steps in a use case diagram. Activities modelled can be sequential and concurrent [3].

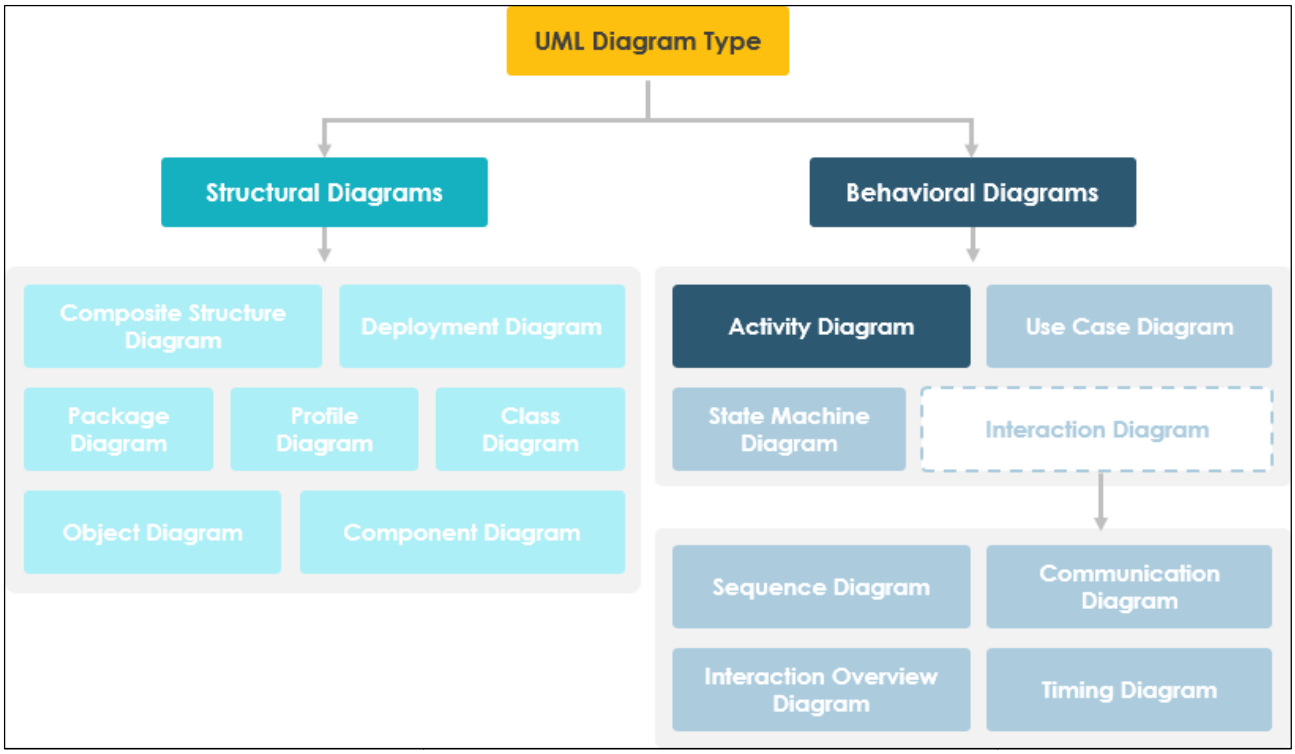

Figure 2: UML Activity Diagram Classification

3.2 When to Use Activity Diagrams

Activity Diagrams describe how activities are coordinated to provide a service which can be at various levels of abstraction. Typically, an event needs to be achieved by some operations, particularly where the operation is intended to achieve several different things that require coordination, or how the events in an individual use case relate to one another where activities may overlap and require coordination. It is also suitable for modelling how a collection of use cases coordinates to represent business workflows, an example of how an activity diagram for this might be developed is given below:

1. Identify candidate use cases, through the examination of business workflows
2. Identify pre- and post-conditions (the context) for use cases
3. Model workflows between/within use cases

4. Model complex workflows in operations on objects
5. Model in detail complex activities in a high-level activity Diagram

An activity diagram is an important behavioural diagram in UML, used to describe dynamic aspects of the system. Activity diagrams are an advanced version of flow charts that model the flow from one activity to another.

Below in Figure 3, we show an example flowchart of a Blood Pressure (BP) Management Module for a Diabetes CDS service, which encodes the decision support logic presented in the NICE diabetes guideline – blood pressure management (2015 version, chapter 1.4) [4].

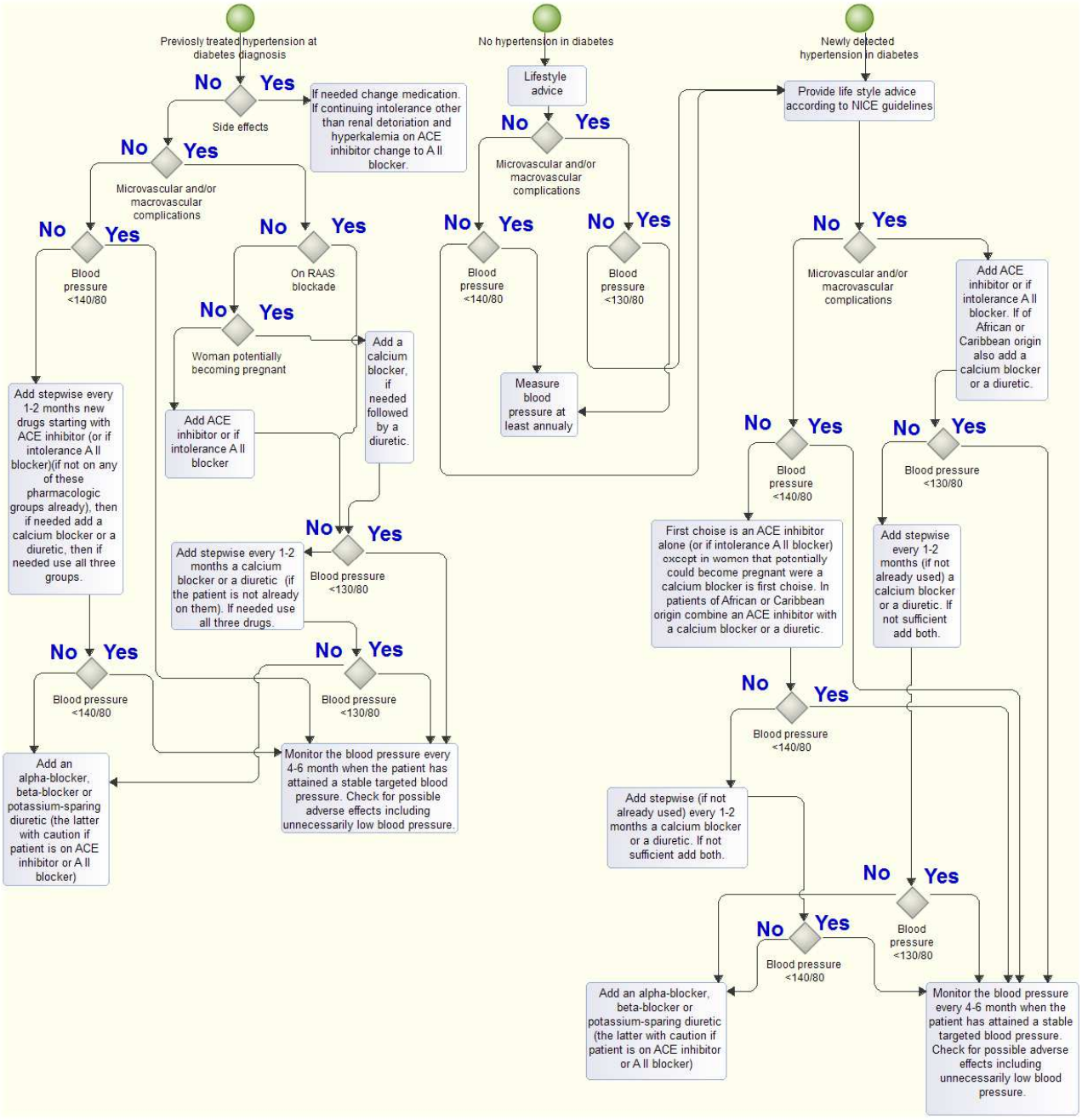

Figure 3: Diabetes - Blood Pressure Management [5, Figure 3]

4. CDS Hooks

The CDS Hooks specification describes the RESTful APIs and interactions to integrate Clinical Decision Support (CDS) between CDS Clients (typically Electronic Health Record Systems (EHRs) or other health information systems) and CDS Services. All data exchanged through the RESTful APIs must be sent and received as JSON structures and must be transmitted over channels secured using the Hypertext Transfer Protocol (HTTP) over Transport Layer Security (TLS), also known as HTTPS and defined in RFC2818 [1].

The CDS Hooks application programming interface (API) is a specification that builds on the FHIR core specification to describe how an electronic health record (EHR) can automatically invoke external decision support service based on events that occur during normal application use. The output that is produced by this system will be in the forms of cards that are required to be actioned by the user. The user action will be in the form of advice, or a request for user input as proposed by the system in relation to the patient's holistic care plan [1].

Using the same example of blood pressure management in diabetes, the flowchart (Figure 3) has been adapted into an implementable one with executable conditions, CDS hooks information and suggestion cards (Figure 4, Figure 5) [6]. The details of the decision points of the flowchart are explained in Table 1. The ICD (International Code of Diseases) INC and ATC codes in the table are used to unambiguously define the conditions within the guideline. These codes are assessed and mapped local codes when necessary, during the implementation phase. The flowcharts in Figure 4 and Figure 5 are not an exact match of the flowchart in Figure 3. In Figure 3, the blood pressure was immediately checked whether it is below the set thresholds after recommending a new drug. However, in practice it will be checked at the next control visit after the patient has used these drugs. After checking the NICE guideline, a recommendation of scheduling a control visit after 1-2 months is introduced, and the blood pressure measurements are checked at the control visit when the CDSM is invoked a second time. Figure 4 and Figure 5 show the changed control flow [6].

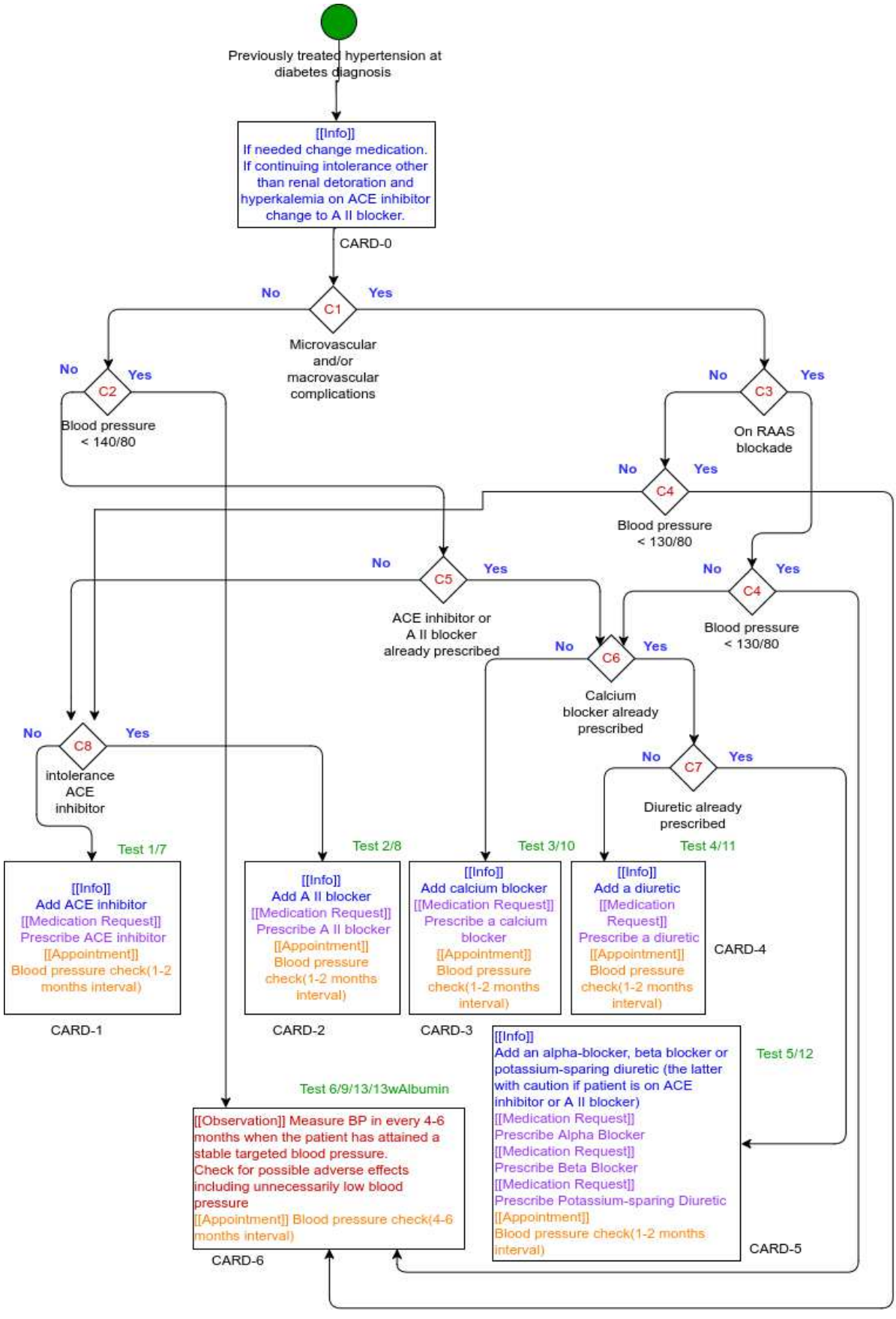

Figure 4: First half of the BP management flowchart [6, Figure 2]

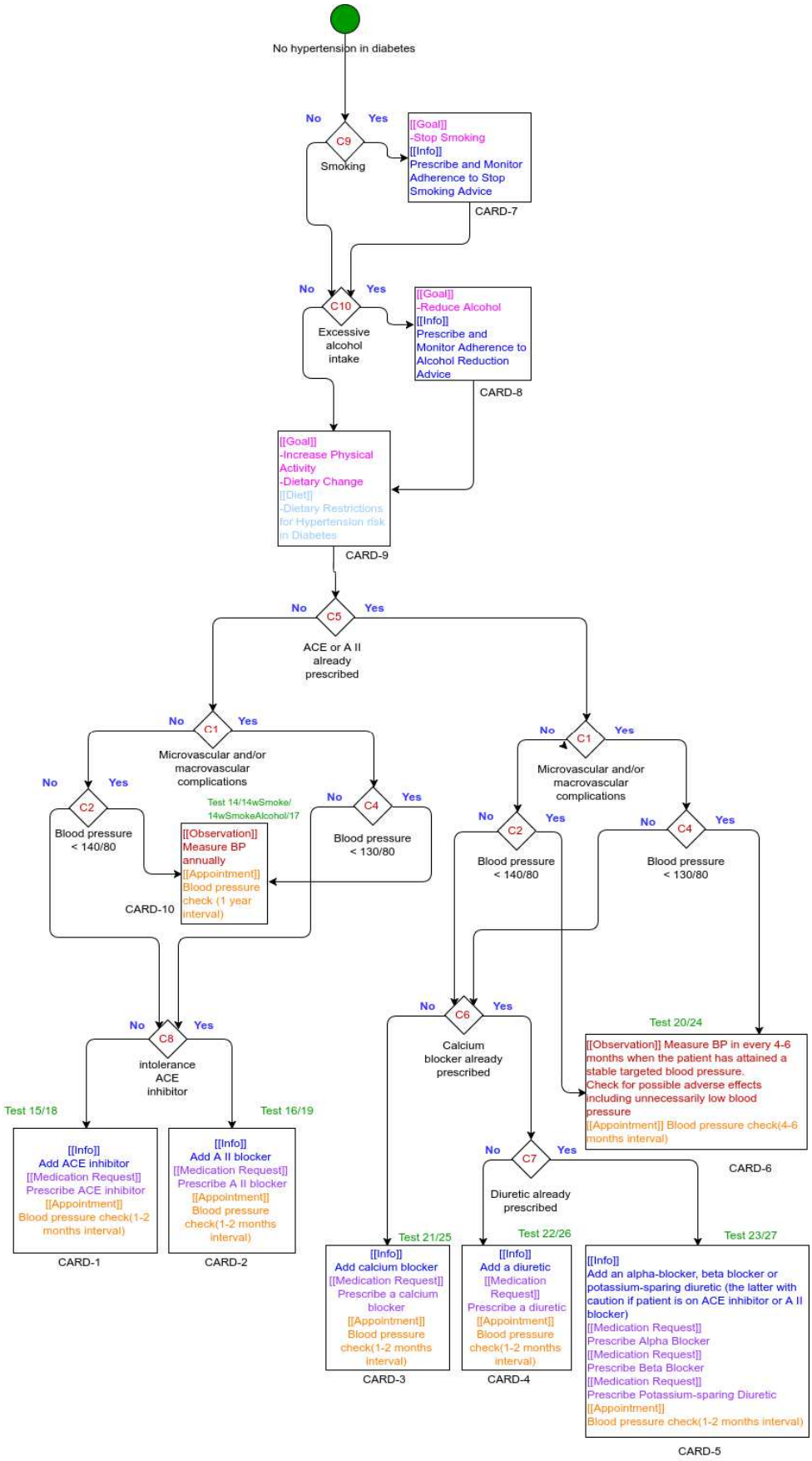

Figure 5: Second half of the BP management flowchart [6, Figure 3]

Table 1: Blood pressure management module condition table [6, Table 4]

Condition No	Condition Clause
C1	If one of the following conditions exists: ICD[E11.2A, E11.2B, E11.4B, E11.4C, E11.4D, G63.2] OR If albumin secretion in urine is ≥ 30 mg/l OR ≥20 µg/min OR ≥30 mg/24h (depending how it is presented)
C2	If systolic blood pressure (LOINC[8480-6]) < 140 and diastolic blood pressure (LOINC[8462-4]) < 80 (Both from 55284-4)
C3	If medication ATC[C09] exists
C4	If systolic blood pressure (LOINC[8480-6]) < 130 and diastolic blood pressure (LOINC[8462-4]) < 80 (Both from 55284-4)
C5	If medication ATC[C09AA or C09CA] exists
C6	If medication ATC[C08] exists
C7	If medication ATC[C03] exists
C8	If condition ICD[T46.4X5A] or allergy ATC[C09AA] exists
C9	If observation LOINC[64234-8] (current smoker) has 373066001(yes)
C10	If observation LOINC[74013-4] (alcoholic drinks per day) > 0

4.1 Understanding Data Dependencies

To successfully implement CDS services, we need to identify the data sources for the CIG logic. This is done by the technical partners by using a list of FHIR resources that are expected to be implemented by the system. This is then checked (in the deployment package) against technical interoperability and what the pilot sites offer. For CAREPATH we also need to identify data sources from the home-based devices. Nevertheless, all these sources will interact with the FHIR repository, hence becoming a data interoperability exercise.

Data that will be provided from pilot sites will consist of different categories and will follow international health standards e.g., CDA, FHIR, HL7v2. This data will be stored in HIS consisting of structured and unstructured data. Data from these pilots' sites will be categorised based on their class, e.g., demographics, lab results, medical images, medication, procedures, allergies, vital signs, medical conditions based on problem and symptoms. There is a dependency on WP4 to identify the relevant data sources.

The output from this deliverable (Release 2) will describe the input to Task 3.4 and Task 4.5 for CAREPATH project.

5. Review and Validation of Models

The clinical reference group, primarily supported by the local sites, will examine the guidelines and the scenarios of use to identify where the guidelines may fall short of information. Clinicians will need to understand the gaps and conflicts between single disease guidelines and offer an integrated guideline covering the main conditions being investigated within CAREPATH. This involves another subprocess including identification of care plan, and medication conflicts which will need to be reconciled. Reconciliation happens at various levels: a) guideline, static and documented reconciliation, b) CDS based dynamic reconciliation e.g., drug to drug interactions and c) clinical expertise and judgment reconciliation when the professional will need to assess the plan and discuss it with other experts to find consensus. The project does a and b (to an extent) and we offer the tools for c). Task 3.1 does not provide any clinical content but will facilitate validation of the consolidated guidelines through providing the guideline models for review by the CRG.

5.1 Reference Guidelines

CAREPATH includes the implementation of a polypharmacy module as part of its CDS. Task 3.2 will implement the polypharmacy CDS services, such as drug-drug interactions and others as identified in Task 6.2. Polypharmacy is defined as the concurrent use of multiple (usually more than four) medications or, sometimes, as the unnecessary use of multiple and/or redundant medications. As described in [7], polypharmacy is common in adults older than 65 years, which shows that generally more than half of all patients older than 65 years take more than 5 prescription drugs. The situation is complicated further by over-the-counter medications. Studies regarding such medications show that, especially in certain communities, 90% of the patients take more than 1 and almost 50% take 2 to 4 of these freely available medications. Additionally, because of incomplete case histories and cases of low patient compliance, the medical professionals treating the patient often have incomplete knowledge on which substances the patient is actually using. Patient safety is a problem area and topic of active research in general, as adverse drug events are a serious problem in modern health care. Multiple studies brought this to attention, notably the report" To Err is Human" in the US, however, adverse events are preventable in many cases. Multiple clinical guidelines and screening tools have been developed to check for Potentially Inappropriate Prescribing (PIPs). Mark Beers et al. created a list of medications that can be considered inappropriate for older patients in long-term care in 1991. Beers' criteria were updated regularly and are the basis for other criteria sets, most notably" Screening Tool of Older Persons potentially inappropriate Prescriptions" (STOPP) and" Screening Tool to Alert doctors to the Right Treatment" (START). Both are evidence-based lists of criteria, first published in 2008 and developed in Ireland by a round of experts using the Delphi consensus method. Version 2 of these criteria was published in 2014. STOPP/START resulted in much research interest, many countries and institutions support the tools and consider them appropriate for evaluating prescriptions. Here is an example of the STOPP criteria: The following prescriptions are potentially inappropriate to use in patients aged 65 years and older for cardiovascular system:

1) Digoxin for heart failure with normal systolic ventricular function (no clear evidence of benefit).

2) Verapamil or diltiazem with NYHA Class III or IV heart failure (may worsen heart failure).

3) Beta-blocker in combination with verapamil or diltiazem (risk of heart block).

And here is an example of the START criteria for the respiratory system:

1) Regular inhaled 2 agonist or antimuscarinic bronchodilator (e.g., ipratropium, tiotropium) for mild to moderate asthma or COPD (Chronic Obstructive Pulmonary Disease).

2) Regular inhaled corticosteroid for moderate-severe asthma or COPD, where FEV1 <50

3) Home continuous oxygen with documented chronic hypoxaemia (i.e., pO2 <8.0 kPa or 60 mmHg or SaO2 <89

None of these guidelines are available in a machine-readable format, they were intended to be used manually by medical professionals, which can create a considerable workload. The usage of the paper-based guidelines is likely unrealistic due to time restrictions on medical staff. There is an urgent need to translate such rules into machine readable form and integrate them into decision support systems as part of the medication prescription process making them available in almost real time for medical doctors. CAREPATH will build in this regard on previous efforts by consortium members [7] in Task 3.2.

5.2 Role of CRG

The analysis work of the guidelines identified in D6.1 is being done in Task 6.2. By detailed analysis of the texts the CRG will study the assigned guidelines from D6.1 and select what is relevant to be included in the CAREPATH CDSS. They will also support the development of flowcharts for the CAREPATH guidelines. The CRG/sites will also undertake the following activities (steps to be confirmed):

1. Summarize the result of the reviewed guidelines with reference to the original clinical guideline/chapter for validation.
2. The CRG will make a joint agreement of what recommendations should be used and note any local variations to be considered.
3. The CRG will review and confirm the annotations used in the models, disambiguating potential medical concepts covered by the same term. Code annotation will also contribute to accurate translation of content for deployment in each pilot site.
4. The representatives of each pilot site on the CRG, will distribute the guideline models to appropriate stakeholders in their pilot site, approving the guidelines for deployment, or suggesting customizations, which will be negotiated with the project.

Develop Flowchart Diagrams

The clinical partners will develop if-else-then programming flows structured in decision trees for the clinical guidelines, with help and feedback from technical partners. The flowcharts will represent all the decision making of the collated guidelines.

Review of Formalised Guidelines

The CRG will review the formalised guidelines produced by technical partners to assure their validity/interpretation.

6. Conclusions

This deliverable describes the process and technologies used for modelling clinical guidelines as computer interpretable guidelines and is related to Task 3.1 which defines “Patient-Oriented Computer Interpretable Clinical Guideline Modelling”. Flowcharts can be used to model guidelines, then transformed into implementable guidelines with annotations, CDS Hook information and card suggestions. Steps to validate and verify the modelling approaches are also defined. It should be noted that although this initial Clinical Guideline modelling approach has been defined, the formalization and implementation of Clinical Guidelines in CAREPATH is an ongoing task as this is also dependent on other Work Packages which are still in progress. The final version of the guideline specification will be presented in the next release of deliverable D3.1 “Computer Interpretable Guidelines specification of the complete CAREPATH decision support logic” that will be delivered in M12, after the CAREPATH guidelines have been defined in Task 6.2.

7. References

[1] CDS Hooks Specification, https://cds-hooks.org/

[2] FHIR HL7 Fast Healthcare Interoperability Resources (FHIR), http://hl7.org/fhir/

[3] Unified Modelling Language and Activity Diagram, https://www.visual-paradigm.com/guide/uml-unified-modeling-language/what-is-activity-diagram/

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8. Document History

Date	Changes	Version	Authors
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14-02-2022	Updates to descriptions, references	1v5	Sarah Lim Choi Keung
14-02-2022	Updated Technical Information Reviewers Comments	1v6	George Despotou, Bilal Ahamad
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