



POWER2DM

“Predictive model-based decision support for diabetes patient empowerment”

Research and Innovation Project

PHC 28 – 2015: Self-management of health and disease and decision support systems based on predictive computer modelling used by the patient him or herself

POWER2DM D4.4 (or D4.3.1)

External EHR/PHR Integrators

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TABLE OF CONTENTS

Table of contents.....	4
1 Introduction.....	5
1.1 Purpose and Scope.....	5
1.2 References.....	5
2 Integration Approach and Architecture.....	5
2.1 Approach for EHR/PHR Integration.....	5
2.2 “cda2fhir” project – Transforming C-CDA to FHIR.....	5
2.3 FHIR based service interface to upload patient summaries to PDS from EHR/PHRs.....	6
3 Functionality Demonstrations.....	7

1 Introduction

1.1 Purpose and Scope

The purpose of deliverable D4.4 is to provide the software implementation and demonstrator for external EHR/PHR integrators to the POWER2DM Personal Data Store. This document provides an implementation report illustrating its architecture, functionalities and demonstration setup showing how it is used.

1.2 References

- D1.2 Requirement Analysis of POWER2DM
- D1.3 Conceptual Design of POWER2DM
- D4.1 Personal Data Model and Service API
- D4.2 Personal Data Store Service Implementation

2 Integration Approach and Architecture

2.1 Approach for EHR/PHR Integration

After our analysis in the state of the art and new developments in the HL7 and other healthcare standardization world and by the suggestions of POWER2DM reviewers for analysing the DECIPHER project (<http://www.decipherpcp.eu>), we have decided to make the integration between the POWER2DM Personal Data Store (PDS) and external EHR/PHR systems over the HL C-CDA (Consolidated Clinical Document Architecture) based patient summaries.

This is also the way suggested by DECIPHER project. The slogan of the project is to "create a PHR EU Adapter and Data Collator". Related with data interoperability, there is a workpackage WP5 European PHR Platform Specification and Reference Implementation and the published deliverable (http://www.decipherpcp.eu/sites/default/files/attachments/decipher_d5_1_phr_platforms_state-of-the-art_v1_0wb_r.pdf) recommends the following;

"In the most desirable case the DECIPHER App can read CCD files from a PHR system by using a web service interface. In any case, it should be possible to download a CCD file (e.g. by using the Blue Button mechanism) and import the data to the DECIPHER App."

CCD is based on HL7 CDA (Clinical Document Architecture) and lately they join their efforts to publish C-CDA (consolidated CDA). We have implemented an open source library (<https://github.com/srdc/cda2fhir>); an integrator to convert these CDA documents to FHIR (which is the base model of POWER2DM PDS).

For the service based integration to pass the C-CDA content between the external EHR/PHR system and POWER2DM PDS, there are two major standard ways; Integrating Healthcare Enterprises (IHE)¹ Cross-enterprise Document Reliable Interchange (XDR) and HL7 FHIR REST "Create" Services with Binary resource type. We choose the implement FHIR based service as both HL7 and IHE are changing their focus to FHIR and also PDS is based on FHIR.

2.2 "cda2fhir" project – Transforming C-CDA to FHIR

cda2fhir is a Java library to transform HL7 CDA R2 instances to HL7 FHIR resources. More specifically, cda2fhir enables automatic transformation of Consolidated CDA (C-CDA) Release 2.1

¹ <https://www.ihe.net/>

compliant document instances to the corresponding FHIR DSTU2 resources, wherever possible implementing the U.S. Data Access Framework (DAF) FHIR Implementation Guide. For this purpose, cda2fhir provides extensible document transformers, resource transformers, data type transformers and value set transformers. The current implementation provides a document transformer for Continuity of Care Document (CCD), but further document transformers, e.g. for Discharge Summary or Referral Note, can be easily introduced by reusing the already existing section and entry transformers. Although the cda2fhir library expects C-CDA R2.1 compliant documents/entries, it has been tested as well with several older document instances compliant with earlier releases of C-CDA. The official HL7 FHIR Validator is also integrated for automated validation of the generated FHIR resources.

All the mappings implemented between CDA artifacts and FHIR resources, data types and value sets are documented in this sheet: C-CDA CCD to FHIR DAF Mapping

Model Driven Health Tools (MDHT) is used for CDA manipulation and HAPI is used for FHIR manipulation. The current implementation produces DSTU2 resources. We are planning to cover STU3 resources as well, after the specification becomes official.

For more information and source codes please check the <https://github.com/srdc/cda2fhir>.

2.3 FHIR based service interface to upload patient summaries to PDS from EHR/PHRs

HL7 FHIR has a resource called Binary (<http://hl7.org/fhir/DSTU2/binary.html>) for handling binary content. Typically, Binary resources are used for handling content such as:

- CDA Documents
- PDF Documents
- Medical Images

Therefore, as proposed in HL7 FHIR standard, we use the "create" operation of FHIR REST Service for Binary resources to get patient summaries (as C-CDA documents) from external EHR/PHR systems and integrate the information into PDS as FHIR resources.

Binary resource is very simple and has the following attributes;

- **contentType: code** - This should be "application/hl7-ccda-2.1+xml" to indicate the patient summary is given in C-CDA format
- **content: base64Binary** – Base64 binary encoded content, that is encoded C-CDA document
- **patient: Reference** – Reference to patient identifier

Figure 1 illustrates the service based integration flow. Here we assume that the POWER2DM Shared Decision Making Web Application deployment for a specific care setting has some type of integration with the underlying EHR/PHR system. So, physicians can trigger data synchronization, during the consultations and the system directly prepare a Patient Summary document in C-CDA format and send it to POWER2DM PDS over the FHIR REST Service interface as FHIR Binary Resource. After receiving the content, the cda2fhir library is used to transform the CDA content into several FHIR resources.

Figure 2 illustrates the same process with a different more simple flow. This time POWER2DM has no direct integration with the EHR/PHR but provide a "Upload Patient Summary" functionality via the POWER2DM Shared Decision Making Web Application. Physician (or Patient) get the patient summary from the EHR/PHR in some way (out-of-scope). Then he uploads it through the application. The same services are used in PDS side so technically there is no difference.

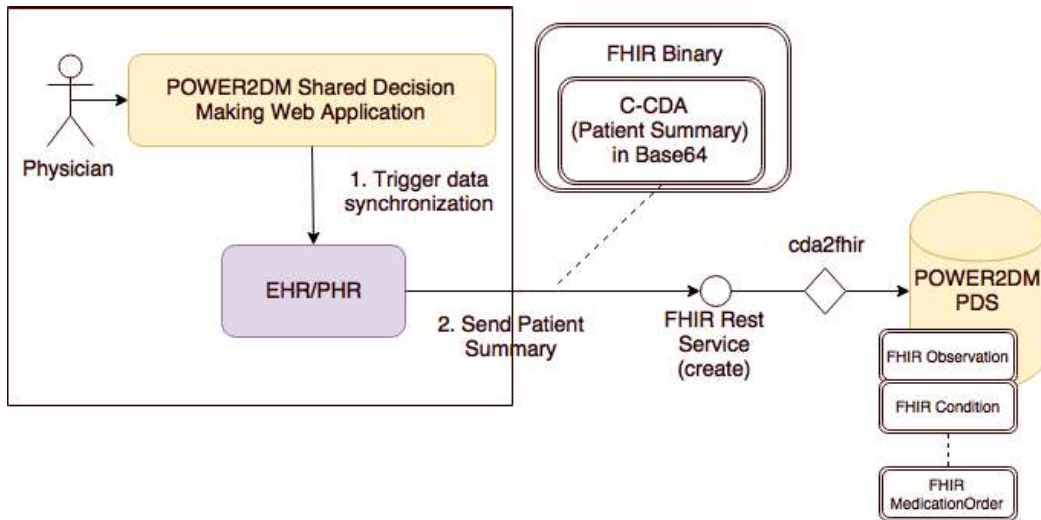


Figure 1 EHR/PHR Service Based Integration Flow (Alternative 1)



Figure 2 EHR/PHR Upload based Integration Flow (Alternative 2)

3 Functionality Demonstrations

This implementation is integrated with PDS. Therefore, for this demonstration first we should run the PDS (See D4.2 for instructions). As this service is not integrated with POWER2DM Shared Decision Making Web Application or other EHR/PHR systems yet, we show the demonstration by using the Postman web tool. We will upload an example Patient Summary to PDS over the service, and show how this is transformed to the FHIR resources in PDS.

We start with empty PDS, with no records, and Figure 3 illustrates this as a query on observations return nothing. Figure 4 illustrates a part of Patient Summary document in C-CDA format that we will submit to the system. As you can see, there is a Blood Pressure observation with LOINC code 8462-4.

Then we submit the document by wrapping it into the FHIR Binary resource as shown in Figure 5 by sending HTTP POST to <http://localhost:8080/fhir/Binary>. The PDS transform the document into FHIR resources and the resources are returned as a Bundle as a response as shown in Figure 6.

Then we query the observation records in PDS with code “8462-4” to show that the observation data in C-CDA is transformed into FHIR Observation (POWER2DM Observation resource). Figure 7 illustrates the results and as you can see from the count; there is one resource with such BP observation. Figure 8 shows the results of query for all observations which returns 4 resources that correspond to 4 observation entries in Patient Summary.

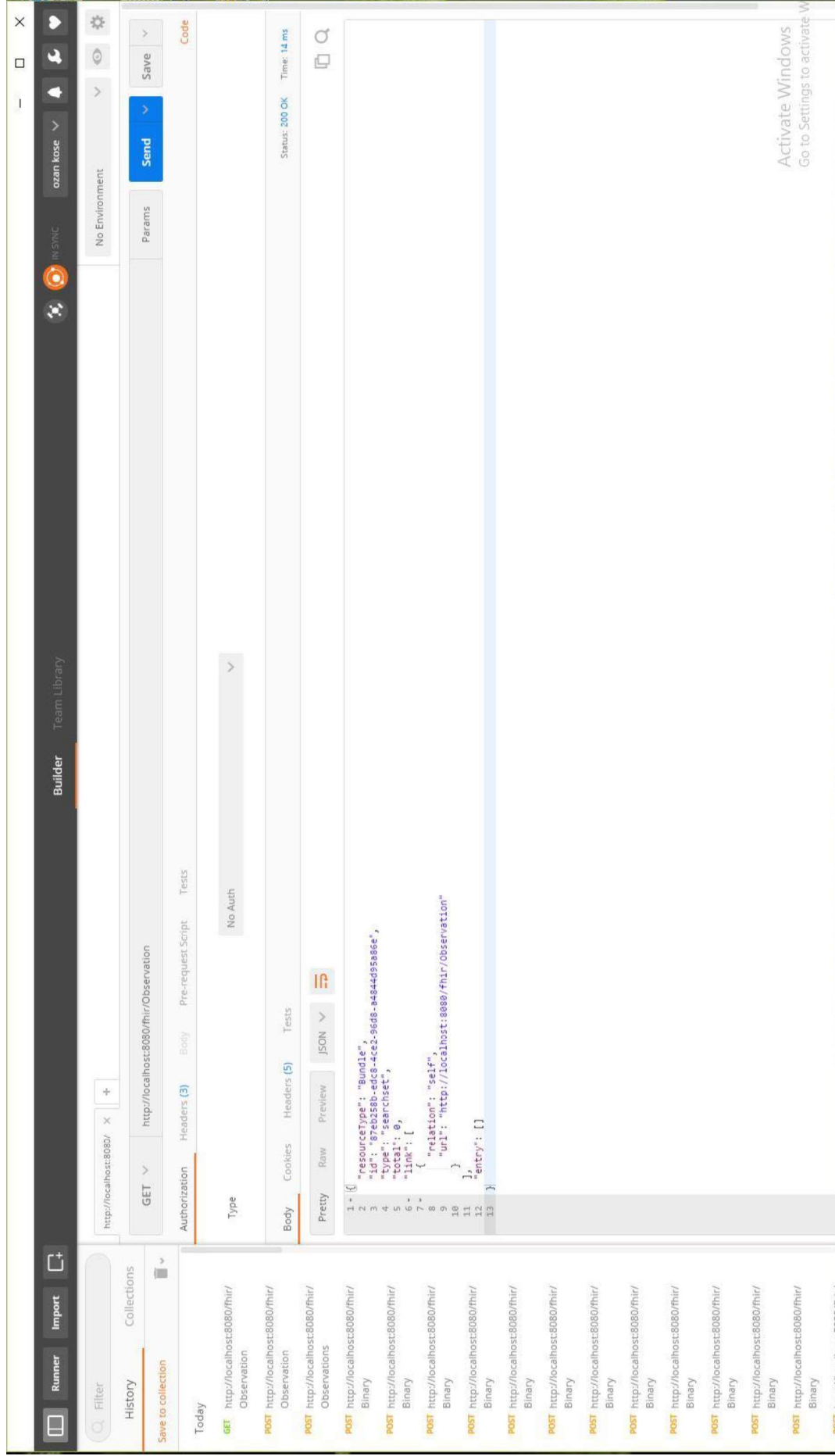


Figure 3 No observations in PDS before calling the service


```

Example_CDA.xml
922 <templateId root="2.16.840.1.113883.10.20.22.4.26" extension="2015-08-01" />
923 <templateId root="2.16.840.1.113883.10.20.22.4.26" />
924 <id root="31b73bd0-cffc-4599-902e-dbe54bc56cb4" />
925 <code code="46680005" codeSystem="2.16.840.1.113883.6.96" codeSystemName="SNOMED CT" displayName="Vital signs" />
926 <!-- A vitals organizer conformant to both C-DA 1.1 and C-DA 2.1 would contain the SNOMED code (46680005) from R1.1 in the root code
and a LOINC code in the translation -->
927 <translation code="74728-7" codeSystem="2.16.840.1.113883.6.1" codeSystemName="LOINC" displayName="Vital signs" />
928 </code>
929 <statusCode code="completed" />
930 <effectiveTime>
931 <low value="201507221810-0500" />
932 <high value="201507221810-0500" />
933 </effectiveTime>
934 <component>
935 <observation classCode="OBS" moodCode="EVN" />
936 <!-- ** Vital sign observation ** -->
937 <templateId root="2.16.840.1.113883.10.20.22.4.27" extension="2014-06-09" />
938 <templateId root="2.16.840.1.113883.10.20.22.4.27" />
939 <id root="1c2748b7-e440-41ba-bc01-cde97d84a036" />
940 <code code="8462-4" codeSystem="2.16.840.1.113883.6.1" codeSystemName="LOINC" displayName="bp Diastolic" />
941 <statusCode code="completed" />
942 <effectiveTime value="20150722" />
943 <value xsi:type="PQ" value="88" unit="mm[Hg]" />
944 <interpretationCode code="N" codeSystem="2.16.840.1.113883.5.83" />
945 </observation>
946 </component>
947 </component>
948 <observation classCode="OBS" moodCode="EVN" />
949 <!-- ** Vital sign observation ** -->
950 <templateId root="2.16.840.1.113883.10.20.22.4.27" extension="2014-06-09" />
951 <templateId root="2.16.840.1.113883.10.20.22.4.27" />
952 <id root="a0e39c70-9674-4b2a-9837-cdf74200d8d5" />
953 <code code="8480-6" codeSystem="2.16.840.1.113883.6.1" codeSystemName="LOINC" displayName="Intravascular Systolic" />
954 <statusCode code="completed" />
955 <effectiveTime value="20150722" />
956 <value xsi:type="PQ" value="145" unit="mm[Hg]" />
957 <interpretationCode code="N" codeSystem="2.16.840.1.113883.5.83" />
958 </observation>
959 </component>

```

Figure 4 Part of Patient Summary record (C-DA format) showing a Blood Pressure measurement

The screenshot displays the Burp Suite REST client interface. At the top, the 'Runner' tab shows a list of requests to 'http://localhost:8080/fhir/'. The 'Builder' tab is active, showing a 'POST' request to 'http://localhost:8080/fhir/Binary'. The 'Code' tab contains a JSON body for the request, which is a binary resource. The 'Response' area is currently empty.

```

1 - {
2   "resourceType": "Binary",
3   "id": "example",
4   "contentType": "application/json",
5   "content": "..."
}

```

Figure 5 Uploading Patient Summary via FHIR Rest Service (HTTP POST for Binary resource)

The screenshot displays a REST client interface with the following components:

- Top Bar:** Runner, Import, Builder, Team Library, ozan kose, IN SYNC, No Environment, Params, Send, Save.
- Request Section:** Method: POST, URL: http://localhost:8080/fhir/Binary, Status: 200 OK, Time: 1674 ms.
- Response Section:** Pretty JSON view of the response body, showing a list of FHIR resources.

```
1 {
2   "resourceType": "Bundle",
3   "id": "45f7288c-abef-4d18-8161-0fddee966875",
4   "type": "batch-response",
5   "entry": [
6     {
7       "resource": {
8         "resourceType": "Composition",
9         "id": "bce5b-e4-f857-41f6-8575-944d91e08b24",
10        "identifier": {
11          "system": "urn:oid:1.16.840.1.113883.19.5.99999.1",
12          "value": "T1662"
13        },
14        "date": "2015-07-22T18:00:00-05:00",
15        "type": {
16          "coding": [
17            {
18              "system": "http://loinc.org",
19              "code": "24133-9",
20              "display": "Summarization of Episode Note"
21            }
22          ]
23        },
24        "title": "170.315.bl_toc_gold_sample2 test data",
25        "status": "preliminary",
26        "confidentiality": "NM",
27        "subject": {
28          "reference": "Patient/bd5ff2e5-9a23-48f3-99c0-2a-ad748d5cf"
29        },
30        "author": [
31          {
32            "reference": "Practitioner/9884802-bfc3-46cc-8bde-157a3a89d96"
33          }
34        ],
35        "attester": [
36          {
37            "mode": [
38              "legal"
39            ],
40            "time": "2015-07-22",
41            "party": {
42              "reference": "Practitioner/48016741-3663-462b-8233-1678963ad12c"
43            }
44          }
45        ],
46        "mode": [
47          "professional"
48        ],
49        "time": "2015-07-22"
50      }
51    }
52  ]
53 }
```

Figure 6 Response for patient summary upload (transformed FHIR resources as Bundle)

The screenshot shows a REST client interface with a top navigation bar containing 'Builder', 'Team Library', and 'Team Library'. The main area is divided into several sections:

- Request Section:** Shows a GET request to `http://localhost:8080/fhir/Observation?code=8462.4`. The status is '200 OK' and the time taken is '103 ms'.
- Response Section:** Displays the JSON response in a 'Pretty' format. The response is a list of 1 observation objects. The first object is expanded to show its details:

```
1- {
2-   "resourceType": "Bundle",
3-   "id": "93803c66-842b-4736-9c55-c2ca122b7219",
4-   "type": "searchset",
5-   "total": 1,
6-   "link": [
7-     {
8-       "relation": "self",
9-       "url": "http://localhost:8080/fhir/Observation?code=8462.4"
10-    }
11-  ],
12-   "entry": [
13-     {
14-       "fullUrl": "http://localhost:8080/fhir/Observation/46624c67-4a95-861c-3a682d66c531",
15-       "resource": {
16-         "resourceType": "Observation",
17-         "id": "46624c67-4a95-861c-3a682d66c531",
18-         "link": [
19-           {
20-             "profile": [
21-               "http://hl7.org/fhir/StructureDefinition/daf-vital-signs"
22-             ],
23-             "versionId": "1",
24-             "lastUpdated": "2017-04-17T16:33:00Z"
25-           },
26-           {
27-             "identifier": [
28-               {
29-                 "value": "ic2748b7-6440-41ba-bc01-dde97d8-a036"
30-               }
31-             ],
32-             "status": "final",
33-             "coding": [
34-               {
35-                 "system": "http://loinc.org",
36-                 "code": "8462.4",
37-                 "display": "BP Diastolic"
38-               }
39-             ],
40-             "subject": {
41-               "reference": "Patient/0d5ff2e5-9a23-4ef3-99c0-2a4a07805cfc"
42-             },
43-             "effectivePeriod": {
44-               "start": "2015-07-22"
45-             },
46-             "valueQuantity": {
47-               "value": 88,
48-               "unit": "mm[Hg]"
49-             }
50-           }
51-         ]
52-       }
53-     }
54-   ]
55- }
```

The interface also includes a 'History' section on the left showing a list of recent requests and responses, and a 'Body' section at the bottom with tabs for 'Raw', 'Preview', and 'JSON'.

Figure 7 Querying observations to check if FHIR resources are created correctly

The screenshot shows a REST client interface with the following components:

- Runner:** Shows a list of requests with a filter and 'Save to collection' option.
- Request:** A GET request to `http://localhost:8080/fhir/Observation` with status 200 OK and time 18 ms.
- Response:** A JSON array containing one FHIR Observation resource. The resource includes fields like `resourceType`, `id`, `type`, `total`, `link`, `relation`, `url`, `entry`, `resourceType`, `id`, `identifier`, `system`, `value`, `status`, `code`, `coding`, `system`, `display`, `subject`, `reference`, `effectivePeriod`, `start`, `valueCodeableConcept`, `coding`, `system`, `code`, `display`, and `meta`.

```

1 * {
2   "resourceType": "Bundle",
3   "id": "190c3511-41c7-465b-b915-ec08c1b8416f",
4   "type": "searchset",
5   "total": 4,
6   "link": [
7     {
8       "relation": "self",
9       "url": "http://localhost:8080/fhir/Observation"
10    }
11  ],
12  "entry": [
13    {
14      "fullUrl": "http://localhost:8080/fhir/Observation/ccc770be-6db4-4616-8946-7664634992d",
15      "resourceType": "Observation",
16      "id": "ccc770be-6db4-4616-8946-7664634992d",
17      "identifier": [
18        {
19          "system": "urn:oid:1.6.840.1.113883.19",
20          "value": "123456789"
21        }
22      ],
23      "status": "final",
24      "code": {
25        "coding": [
26          {
27            "system": "http://loinc.org",
28            "code": "72166-2",
29            "display": "Tobacco smoking status (NIS)"
30          }
31        ]
32      },
33      "subject": {
34        "reference": "Patient/0d5ff2a5-9a23-4af3-99c0-284a07e8d5cf"
35      },
36      "effectivePeriod": {
37        "start": "2015-07-22"
38      },
39      "valueCodeableConcept": {
40        "coding": [
41          {
42            "system": "http://snomed.info/ict",
43            "code": "449880e2",
44            "display": "Current every day smoker"
45          }
46        ]
47      },
48      "meta": {
49

```

Figure 8 Query for all observations