Capturing Provenance, Evolution and Modification of Clinical Protocols via a Heterogeneous, Semantic Social Network

George Drosatos
Nick Portokallidis, George Drosatos and Eleni Kaldoudi

School of Medicine, Democritus University of Thrace, Alexandroupoli, Greece
A novel approach to describe, organize, manage, trace, use and reuse clinical protocols, based on a heterogeneous semantic social network

- The proposed approach allows
  - Semantic tagging
  - Semantic enrichment

- Main advantages
  - Tracing protocol provenance, evolution and modifications
  - Protocol meta-description, irrespective of protocol source format
  - Interlinking to related scientific sources (e.g. scientific publications, PHR, etc.) and bodies (e.g. protocol issuing bodies, hospitals, etc.)
Formal care plans

- **Clinical guidelines**
  Systematically developed recommendations to address various clinical problems

- **Clinical protocols**
  Detailed algorithms on how to address a particular clinical problem (based on guidelines)

- **Care pathways**
  Care algorithms integrating multidisciplinary tasks for patient care in and outside the hospital (based on guidelines)

- **Other, e.g. clinical trial protocols, clinical practice guidelines, ...**
Examples of formal care plans

Diabetes Diagnosis

Criteria for Diabetic Diagnosis: 4 options

A1C ≥ 6.5%* 
Performed using NCSP certified method and standardized to DCCT assay

FPG ≥ 126 mg/dL (7.0 mmol/L)*
Fasting defined as no caloric intake for ≥8 hrs

2-hr PG ≥ 200 mg/dL (11.1 mmol/L) during OGTT (75-g)*
Performed as described by the WHO, using glucose load containing the equivalent of 75 g anhydrous glucose dissolved in water

Random PG ≥ 200 mg/dL (11.1 mmol/L)
In persons with symptoms of hyperglycemia or hyperglycemic crisis

*In the absence of unequivocal hyperglycemia results should be confirmed using repeat testing
- Unless clinical diagnosis is clear, same test to be repeated using a new blood sample for confirmation
- 2 discordant results? Result above cutpoint should be repeated

American Diabetes Association.

Clinical protocol

Presentation within 24 hours of acute stroke symptoms, wake-up strokes, mRS ≤ 3 pre-stroke

YES
STAT non-contrast CT

NO
Routine Stroke Work Up

Symptoms < 4.5 hours
IV-rPA as per institution protocol
STAT CTA arch to vertex, CT perfusion

Symptoms ≥ 4.5 hours

YES
Consider Endovascular Therapy

NO
Routine Stroke Work Up

Care pathway

Managing type 2 diabetes
Patient education
Care for people in hospital
Dietary advice

Blood glucose-lowering therapy
Managing cardiovascular risk
Identifying and managing long-term complications
Managing blood lipids
Managing blood pressure

Anti-thrombotic therapy
State of the art

- Protocol description languages
  - GLIF, EON, Asbru, GUIDE, PROforma, PLAN, ...
- Protocol execution engines and management platforms
  - GLEE, SAGE, DeGeL, NewGuide, SpEM, Tallis, ArezzoTM, HeCaSe2, ...
- Current unmet needs
  - Choose the right protocol
  - Choose the right modification of a protocol (to meet local set-up)
  - Trace protocol use and modification history
  - Trace to protocol provenance, including medical evidence and issuing body
  - Record outcomes of protocol clinical application (e.g. for protocol evaluation)
Our contribution

- **Formal protocol meta-description**
  - eCP ontology

- **Versatile protocol ‘meta-repository’**
  - Heterogeneous social network
ECP ONTOLOGY

Conceptual model of care plan meta-description
Conceptual model of care plan meta-description
Conceptual model of care plan meta-description

- Title
- Description
- Genre
- Type
- Related health issue

Formal care plan

Relationships:
- Has
- 1...N
- 0...1
Conceptual model of care plan **meta**-description

Diagram showing relationships:
- **Formal care plan**
  - **Title**: 1
  - **Description**: 0...1
  - **Issueing body**: 1
    - **Is issued by**: 1
  - **Evidence source**: 0...N
    - **Is endorsed by**: 1...N

Classification:
- **Genre**
- **Type**
- **Related health issue**

General description:
- **Title**: 1
- **Description**: 0...1
Conceptual model of care plan meta-description

- **Title**
- **Description**
- **Genre**
- **Type**
- **Related health issue**
- **Issuing body**
  - is issued by
  - is endorsed by
- **Evidence source**
  - 1 to 1
  - 0 to N
- **Quality of evidence**
  - low
  - very low
- **Strength of recommendation**
  - high
  - moderate
  - low
  - very low
  - strong
  - weak
Conceptual model of care plan **meta**-description
Conceptual model of care plan meta-description

- **title**
- **description**
- **genre**
- **type**
- **related health issue**
- **quality of evidence**
- **strength of recommendation**
- **quality & level of recommendation**
- **is issued by**
- **is endorsed by**
- **initiated by**
- **has**
- **requires**
- **is part of**

Formal care plan

- **issuing body**
- **evidence source**
- **outcomes**
- **observables**
- **resource**

General description

Classification

Quality & level of recommendation

High
Moderate
Low
Very low

strength

weak

quality of evidence

is a value of
Conceptual model of care plan meta-description

- **Title**: 1
- **Description**: 0..1
- **Genre**: 1..N
- **Type**: 1..N
- **Related Health Issue**: 1..N
- **Quality of Evidence**: low, very low
- **Quality & Level of Recommendation**: high, moderate, low, strong, weak
- **Outcomes**: 1..N
- **Issuing Body**: 1
- **Evidence Source**: 1..N
- **Is Issued By**: 0..N
- **Is Endorsed By**: 0..N
- **Resource**: 0..N
- **Observables**: 1..N
- **Strength of Recommendation**: high, moderate, strong, weak
- **Strength**: 1..N
- **Source File**: has identifier, location, format, copyright
- **Initiated By**: 1..N
- **Requires**: 0..N
- **Is Part Of**: 1..N

The diagram illustrates the relationships and properties of a formal care plan, including its general description, classification, quality of evidence, outcomes, and associated observables and resources.
Conceptual model of care plan **meta**-description

- **Title**
- **Description**
- **Genre**
- **Type**
- **Related health issue**
- **Quality of evidence**
  - **High**
  - **Moderate**
  - **Low**
  - **Very low**
  - **Strength of recommendation**
    - **Strong**
    - **Weak**
- **Issuing body**
  - 1
- **Evidence source**
  - 1...N
- **Has is issued by**
- **Has is endorsed by**
- **Has is a deviation of**
- **Formal care plan**
- **Outcomes**
  - 1...N
- **Source file**
  - Identifier
  - Copyright
  - Location
  - Format
- **Observable condition**
  - 1...N
- **Requires**
  - 0...N
- **Is part of**
- **Observable**
  - 1...N
Ontology implementation

- Implemented with OWL2 using Protégé
- Integrated with commonly used standards and controlled vocabularies:
  - ICD-10, SNOMED-CT, QUDT, UO, GRADE and UMLS
Ontology implementation

Available online in: http://purl.bioontology.org/ontology/ECP
E-CLINPRO: CLINICAL PROTOCOL MANAGEMENT SYSTEM
Social networks

Connections and relationships among humans

on line digital content, resources, concepts...

Facebook
LinkedIn
CarePages
Object centered social networks

People interacting on a common social object

on line digital content, resources, concepts...

ResearchGate
Academia
PatientsLikeMe
Heterogeneous social networks

Human and non-human entities are all treated alike, as actors

on line digital content, resources, concepts...
e-ClinPro heterogeneous network

- Health units
- Patients
- Issuing bodies
- People
- Information
- Medical practice
  - Medical conditions
  - Observables
  - Infrastructure
- Formal care plans
- Medical evidence
- Procedures
Clinical protocol provenance, evolution and modification

- **Provenance**
  - Issuing bodies
  - Clinical practice guidelines
  - Scientific evidence sources

- **Evolution**
  - Update of a previous version, e.g. due to new evidence

- **Modification**
  - Infrastructure limitations, e.g. lack of a diagnostic equipment
  - Clinical restrictions, e.g. due to concurrent clinical protocols
  - Patient choices and objections, e.g. due to religion
  - Insurance policy constraints, e.g. to firstly perform a lower cost procedure
  - Adaptation to local settings, e.g. different language
  - Restrictions due to comorbidities
Example of clinical protocols’ relationships in the semantic social network

Health units

University General Hospital of Alexandroupolis

Issuing bodies

NICE
KDIGO

Care plans

Acute kidney injury (Protocol)

Acute kidney injury (Protocol) - Greek

Acute kidney injury (Guideline)

Acute coronary syndrome (Pathway)

Blood pressure in CKD (Guideline)

Uses

issues

parent of (provenance)

modified to (translation)
Semantic tagging and interlinking

- Profile of clinical protocol based on the eCP ontology\(^1\)

- Entry point: observables and observable condition described via the CARRE ontology\(^2\)

- Issuing bodies and healthcare units are described following the SWRC ontology\(^3\)

- Semantic tagging of medical terms with external resources via ICD-10 and SNOMED

- Medical evidence description based on the Bibliographic Ontology (via PubMed identifier and DOI)

---

\(^1\)Kaldoudi, E., Drosatos, G., Portokallis, N. and Third, A., 2016. An Ontology Based Scheme for Formal Care Plan Meta-Description. In XIV Mediterranean Conference on Medical and Biological Engineering and Computing 2016 (pp. 785-790). Springer International Publishing.


Semantic tagging and interlinking

- General Information
- Technical Information
- Clinical Care Plan
- Evolution
- Exit Points

- Issuing body
- Health Unit
- Entry Point

- observables
- conditions
- resources

- ICD10, SNOMED-CT

- Bibliographic Ontology
  (PubMed ID & DOI)
E-CLINPRO: IMPLEMENTATION
e-ClinPro implementation

- **Backend**
  - Server: NodeJS
  - API: LoopBack framework
  - Database: MongoDB

- **Frontend**
  - Visual Interface: AngularJS
  - Graph visualizations: Vis.JS

- **Integration with**
  - NCBO BioPortal API
  - PubMed API

- **Available online in:**
  http://iris.med.duth.gr/research/ecp
E-ClinPro: Login
E-ClinPro: Dashboard

- **Dashboard**
  - 5 All Care Plans
  - 0 Care Plans I own
  - 0 Care Plans I use
  - 3 Issuing Bodies

**Hello, Hospital of Komotini**
drosatosgr@gmail.com
E-ClinPro: Visualizations
E-ClinPro: Care plans list

- **Helicobacter pylori**
  - **Diagnosis guideline**
    - Helicobacter pylori
    - Dyspepsia
  - **Entry points**
    - Dyspepsia diagnosed AND (Melena diagnosed OR Hematemesis diagnosed OR Weight loss diagnosed OR Dysphagia diagnosed OR Anemia diagnosed)

- **Acute coronary syndrome**
  - **Management pathway**
    - Acute coronary syndrome
    - Stable angina
    - Myocardial infarction
    - Chest pain
    - Hyperglycaemia, unspecified
  - **Entry points**
    - Chest pain yes AND Assessment of chest pain stable OR Assessment of chest pain unstable

- **Helicobacter pylori (Variation)**
  - **Diagnostic guideline (deviation)**
    - Helicobacter pylori
    - Dyspepsia
  - **Entry points**
    - Dyspepsia diagnosed AND (Hematemesis diagnosed OR Weight loss diagnosed OR Dysphagia diagnosed OR Anemia diagnosed)

- **KDOQI Clinical Practice Guidelines for Chronic Kidney Disease: Evaluation, Classification, and Stratification 2002**

- **Diagnostic guideline**
  - Chronic kidney disease stage 1
  - Chronic kidney disease stage 2
Acute kidney injury

Description
The kidneys clean the blood by removing waste products. Many different conditions can lead to the ki...

Genre: Guideline
Type: Management
Related Health Issues:
- Acute nontraumatic kidney injury

Entry points:
- Serum creatinine 300% of baseline OR Serum creatinine measurement 0.4 mg/dL AND Urine 0.3 mL/kg/hr OR Urine 100 mL/24h) OR acute kidney injury diagnosis severe

Exit points:

Issuing Body: NICE
Evidence sources:
E-ClinPro: Edit care plan

Issuing body *

NICE

Select article to add as evidence

Search in pubmed...

1. Improving early detection of chronic kidney disease. PMID: 25816501
   Authors: Larmour KE, Maxwell AP, Courtney AE. ©2015

2. Long-term prognosis after acute kidney injury (AKI): what is the role of baseline kidney function and recovery? A systematic review. PMID: 25564144
   Authors: Sawhney S, Mitchell M, Marks A, Ruck N, Black C. ©2015

Submit
E-ClinPro: Initial condition builder

User friendly output:

( (Serum creatine kinase measurement $\geq 300\%$ of baseline OR Serum creatine kinase measurement $\geq 0.4$ mg/dL) AND (Urine $\geq 0.3$ mL/kg/hr OR Urine $\geq 100$ mL/24h) ) OR acute kidney injury diagnosis $=$ severe
CONCLUSION
Work in progress

• Extensive ontology and system evaluation
  Structured interviews and focus groups of different types of system users, including experts, nurses, residents, and medical students

• Support relationships between doctors, patients, and protocols for clinical protocol evaluation based on the assessment of
  – The extent of clinical protocol use
  – Type and number of clinical protocol modifications
  – Outcomes of protocol clinical application
Any questions?

THANK YOU
Acknowledgement

This work was financially supported by the projects

eCP: Development of electronic clinical protocols, (MIS 375876), the Greek National Programme Thales

CARRE Project: Personalized patient empowerment and shared decision support for cardiorenal disease and comorbidities, Grant no. 611140, FP7-ICT (http://www.carre-project.eu/)

both co-funded by the European Commission.