

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

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# Aim

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.)

## BACKGROUND

# 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 Diabetes Diagnosis: 4 options

A1C  $\geq 6.5\%$ \*

Performed in lab using NGSP-certified method and standardized to DCCT assay

FPG  $\geq 126$  mg/dL (7.0 mmol/L)\*

Fasting defined as no caloric intake for  $\geq 8$  hrs

2-hr PG  $\geq 200$  mg/dL (11.1 mmol/L) during OGTT (75-g)\*

Performed as described by the WHO, using glucose load containing the equivalent of 75g anhydrous glucose dissolved in water

Random PG  $\geq 200$  mg/dL (11.1 mmol/L)

In persons with symptoms of hyperglycemia or hyperglycemic crisis

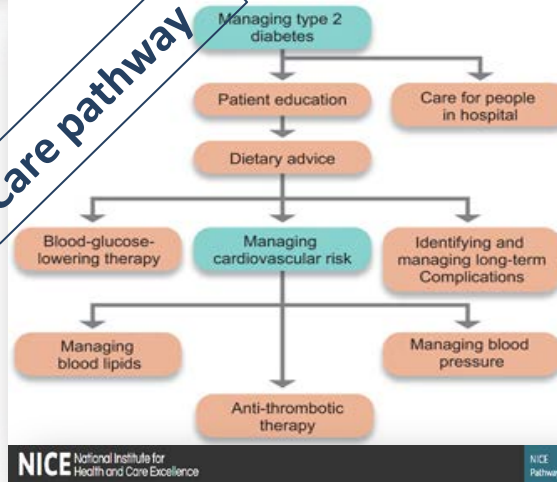
\*In the absence of unequivocal hyperglycemia results should be confirmed using repeat testing

\* Unless clinical diagnosis is clear, same test to be repeated using a new blood sample for confirmation

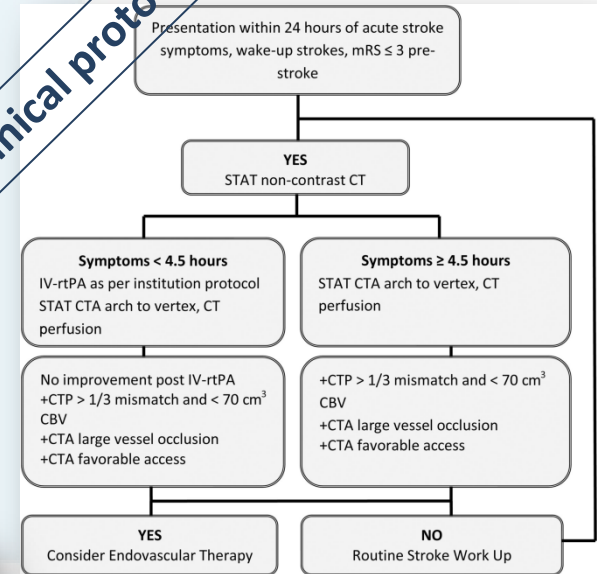
\* 2 discordant results? Result above cutpoint should be repeated



## Care pathway




## Clinical protocol

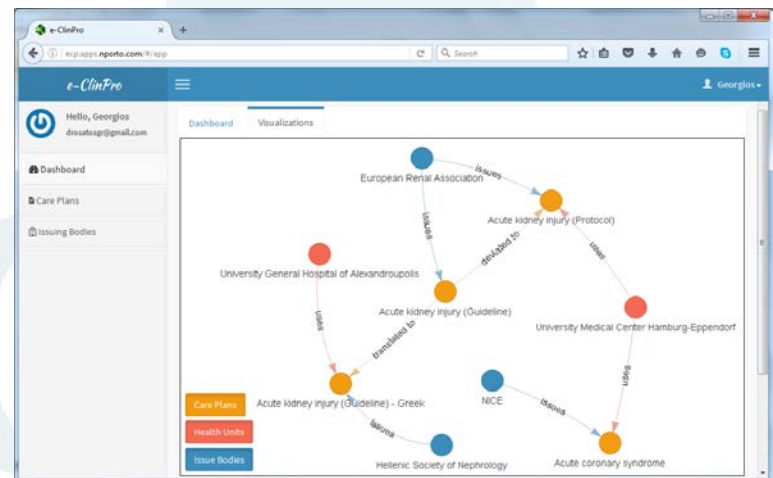
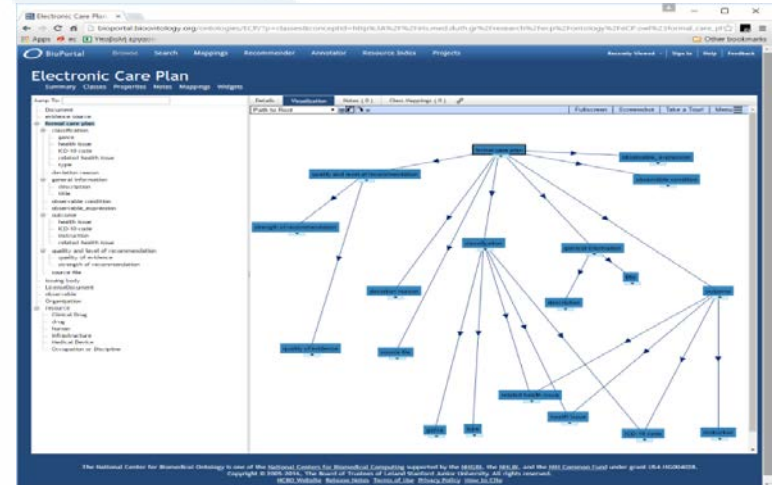


# State of the art

- 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

Kaldoudi, E., Drosatos, G., Portokallidis, 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.



# Conceptual model of care plan meta-description

Ni2016

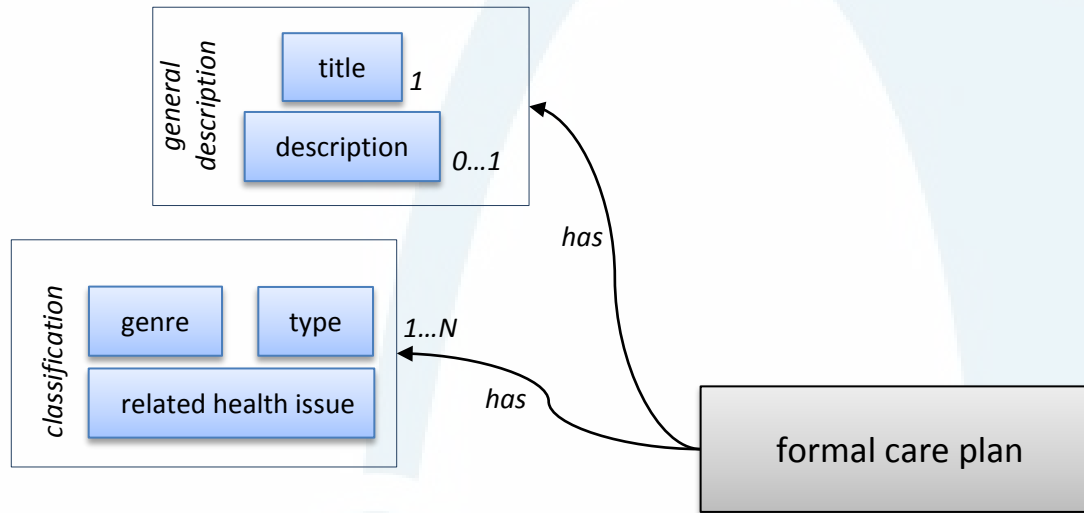
# Conceptual model of care plan meta-description



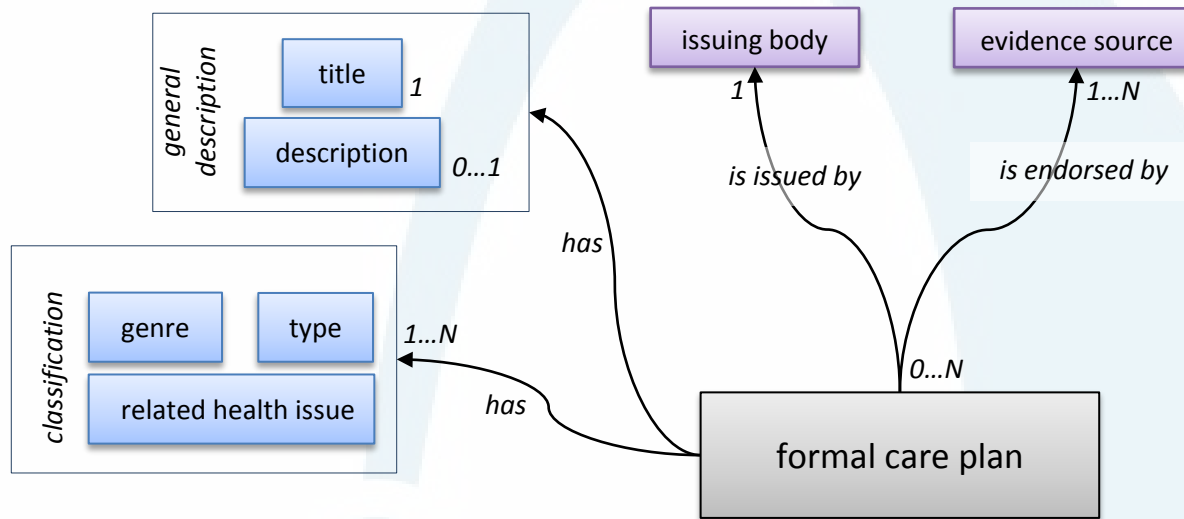
formal care plan

The diagram features a large, light blue, stylized arch that resembles a question mark. In the center of this arch is a gray rectangular box with a thin black border containing the text 'formal care plan'. The background is white with a large, faint, light blue watermark that reads 'Ni 2016'.

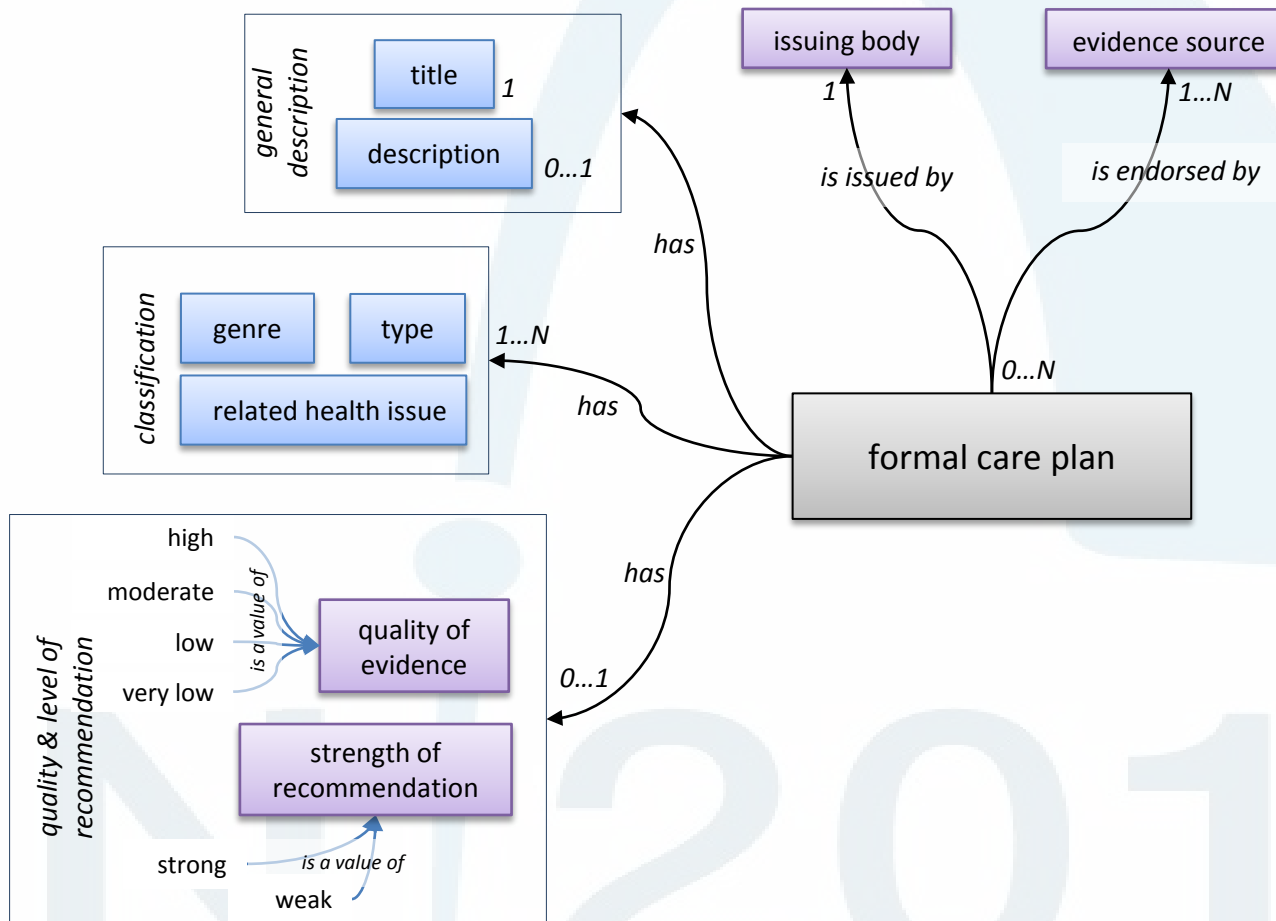
# Conceptual model of care plan meta-description



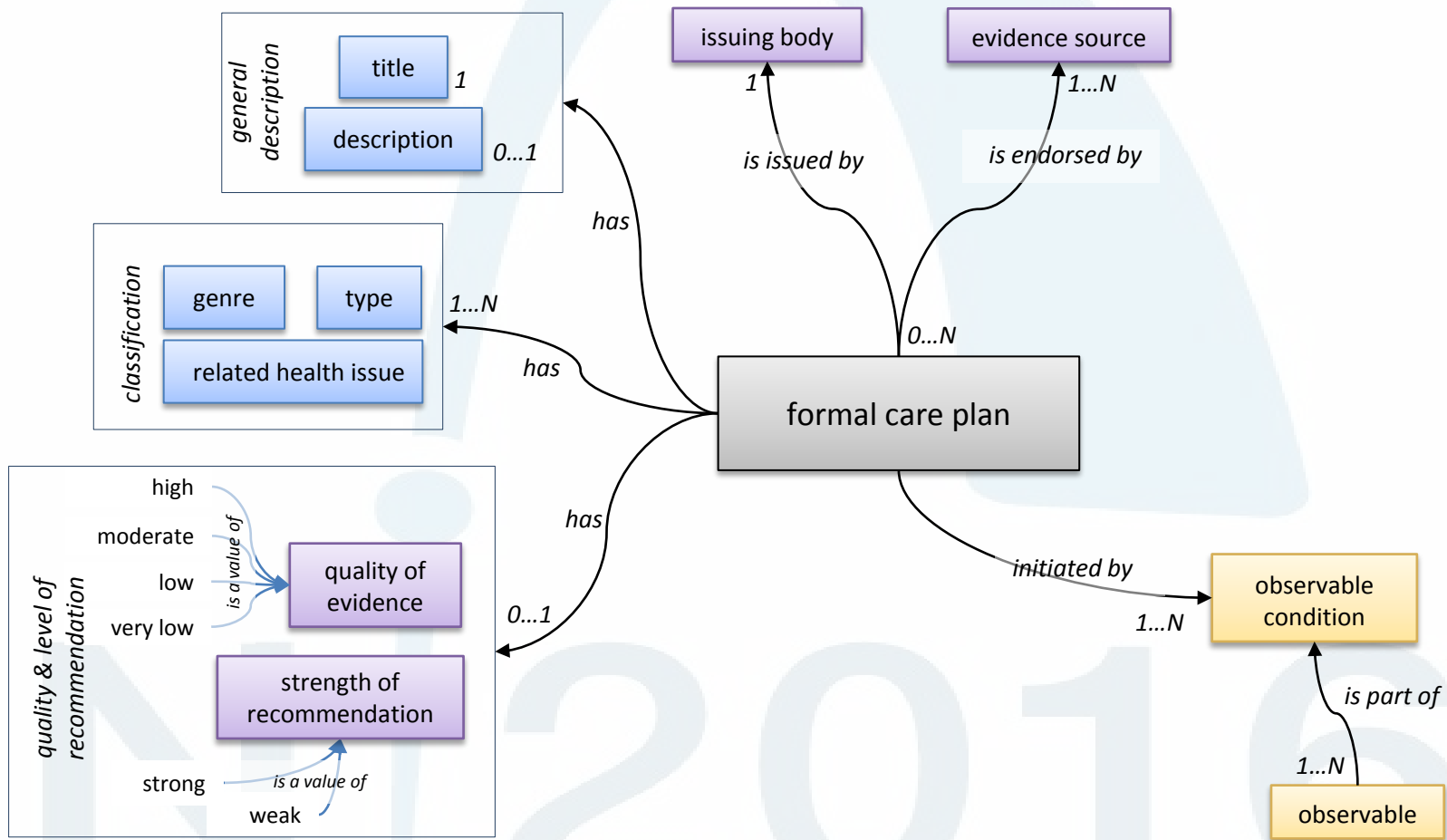
# Conceptual model of care plan meta-description



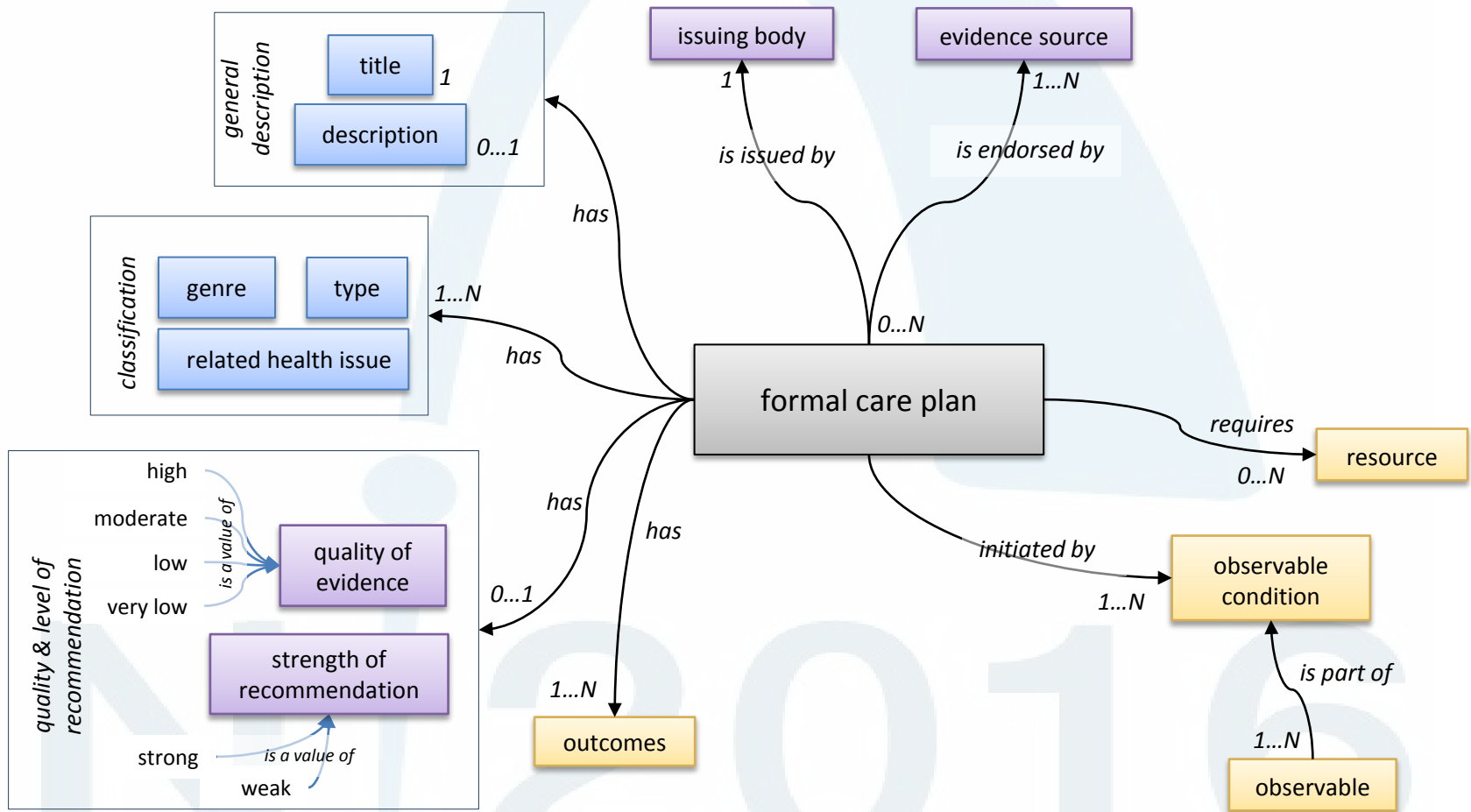
# Conceptual model of care plan meta-description



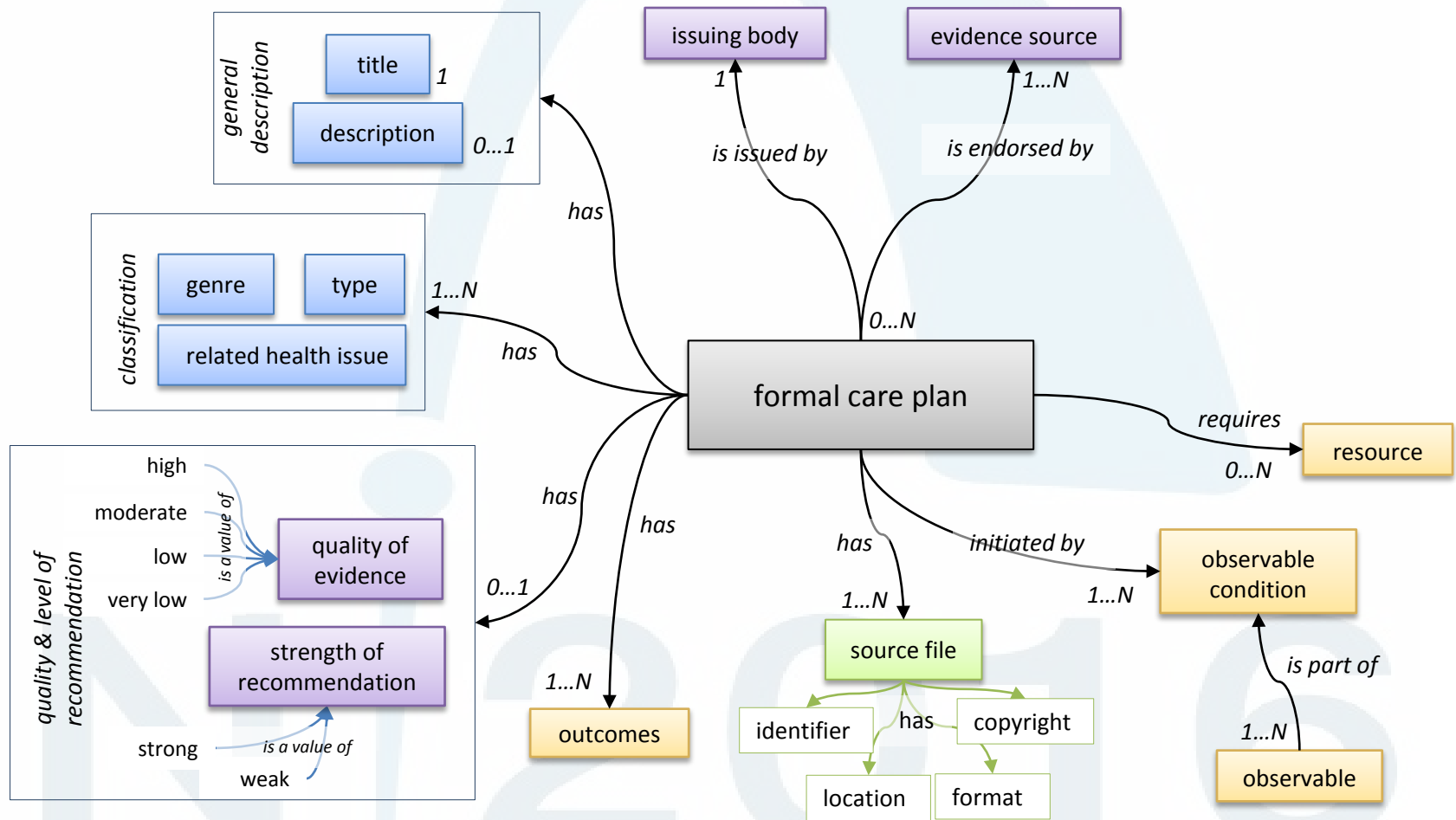
# Conceptual model of care plan meta-description



# Conceptual model of care plan meta-description

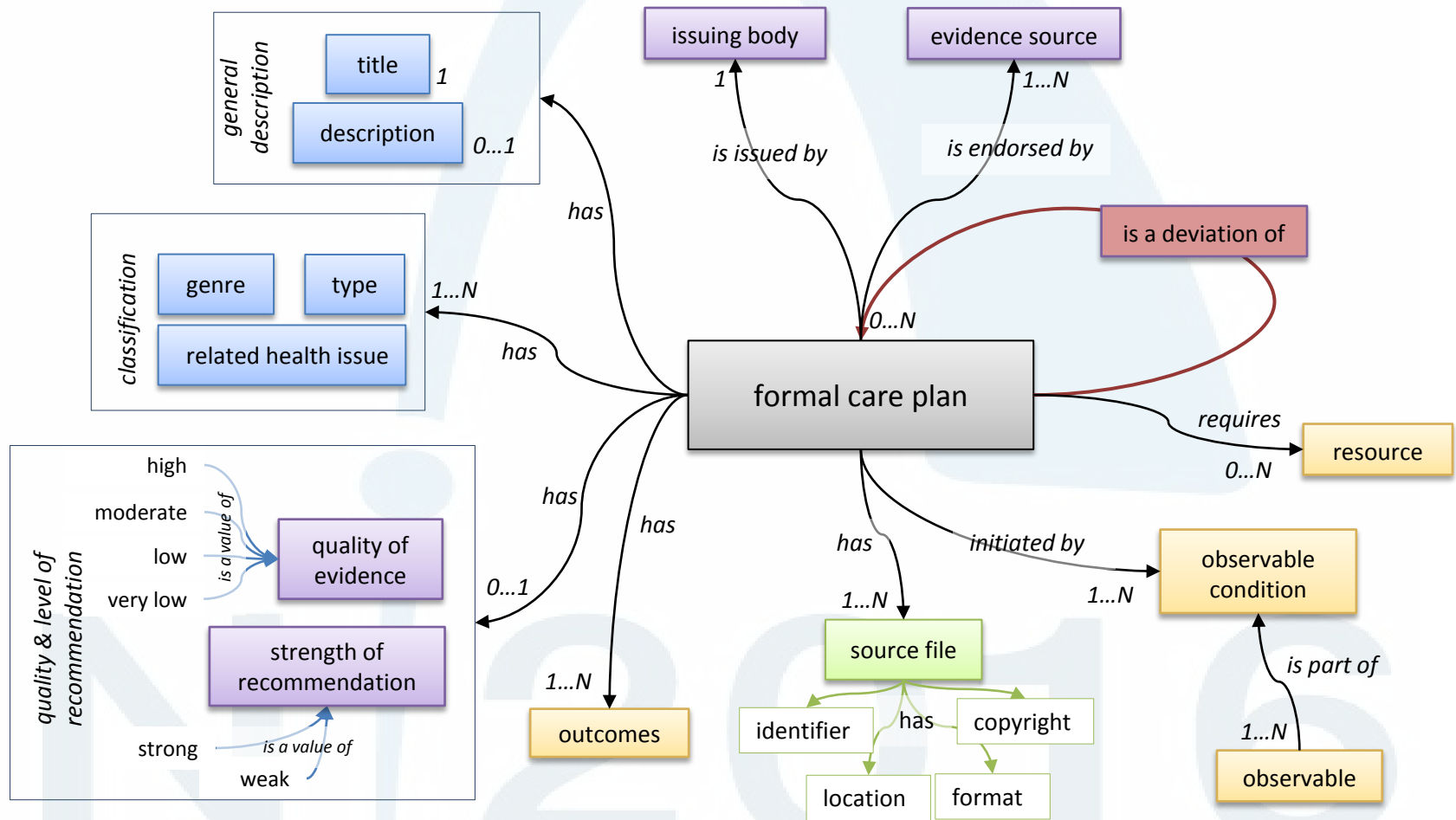


# Conceptual model of care plan meta-description



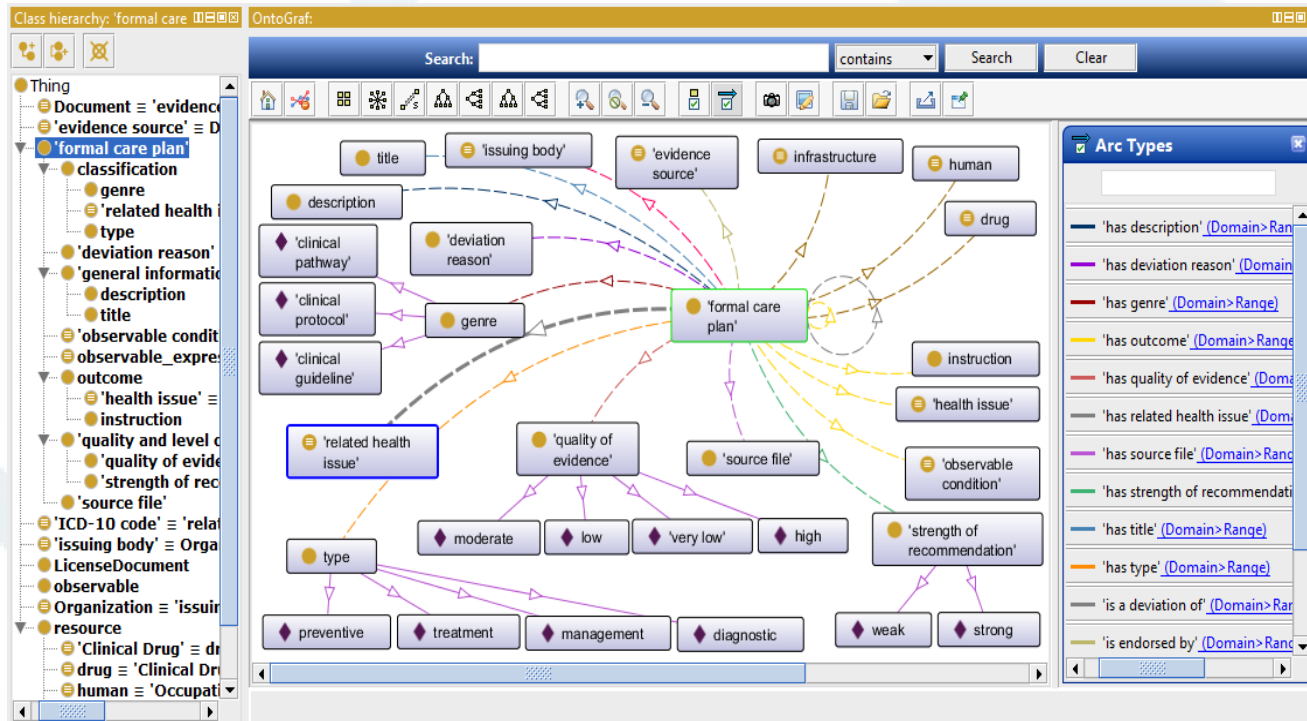


# Conceptual model of care plan meta-description



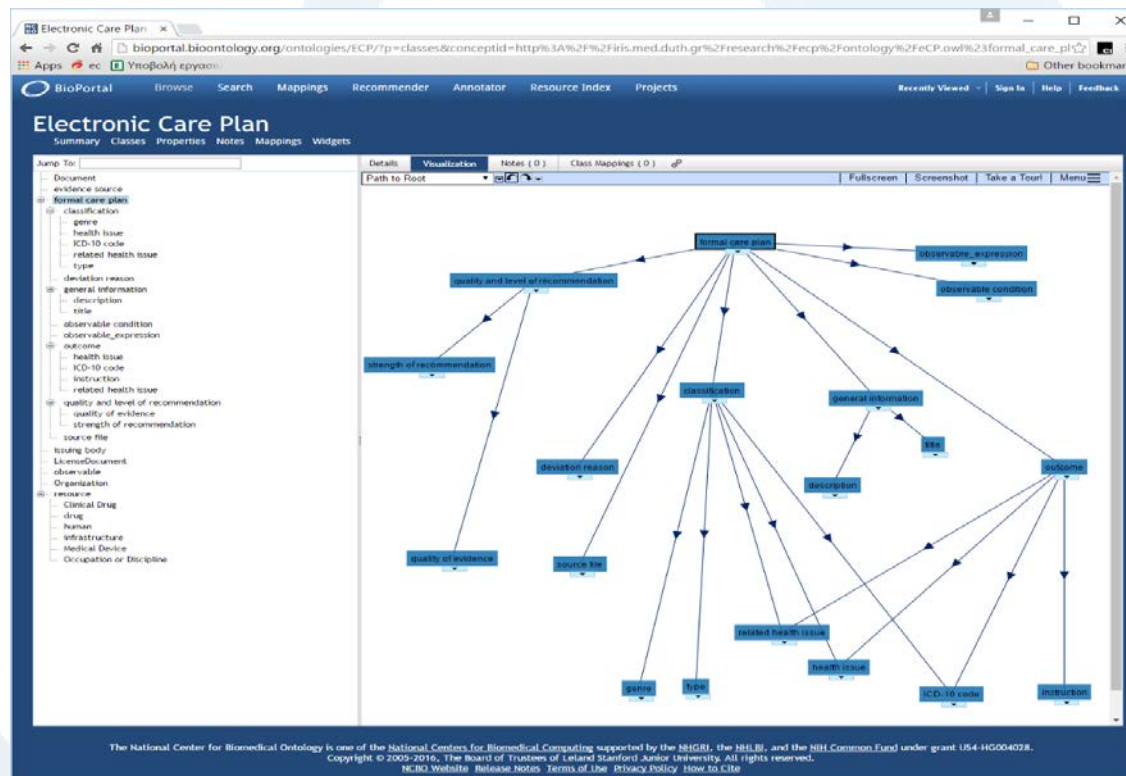
# Ontology implementation

- 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>



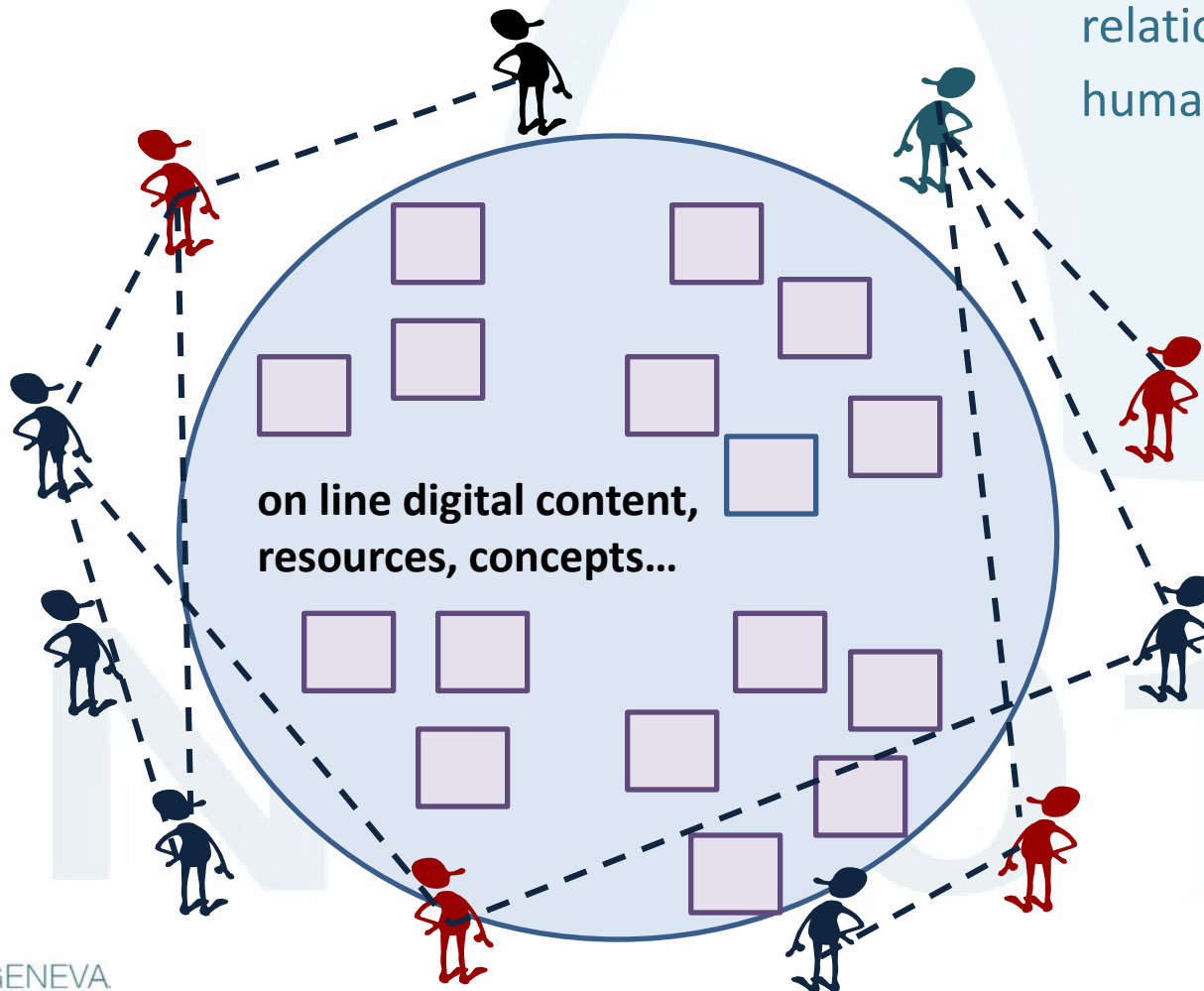


# **E-CLINPRO: CLINICAL PROTOCOL MANAGEMENT SYSTEM**

ni 2016

# Social networks

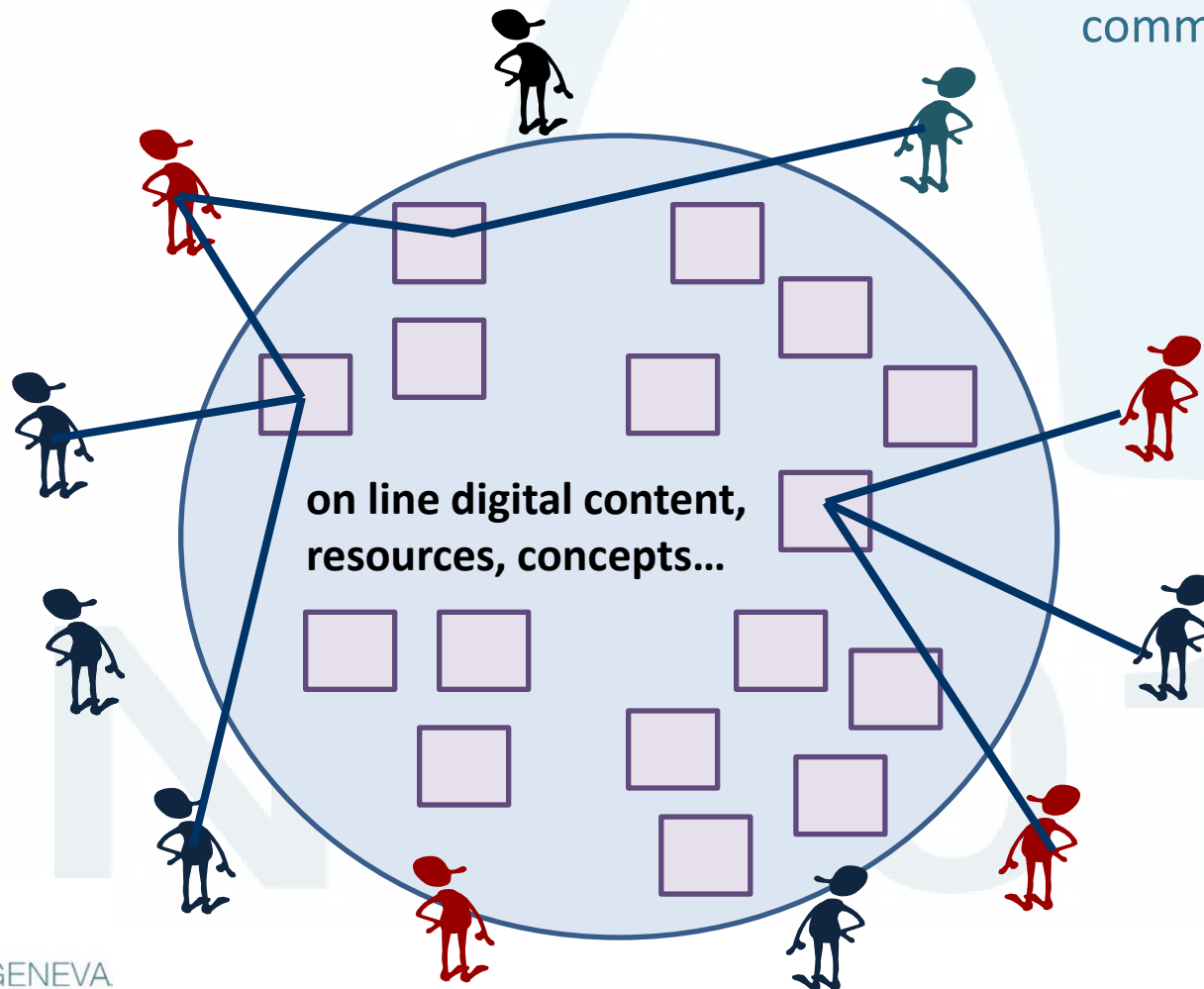
Connections and  
relationships among  
humans



Facebook  
LinkedIn  
CarePages

# Object centered social networks

People interacting on a  
common social object



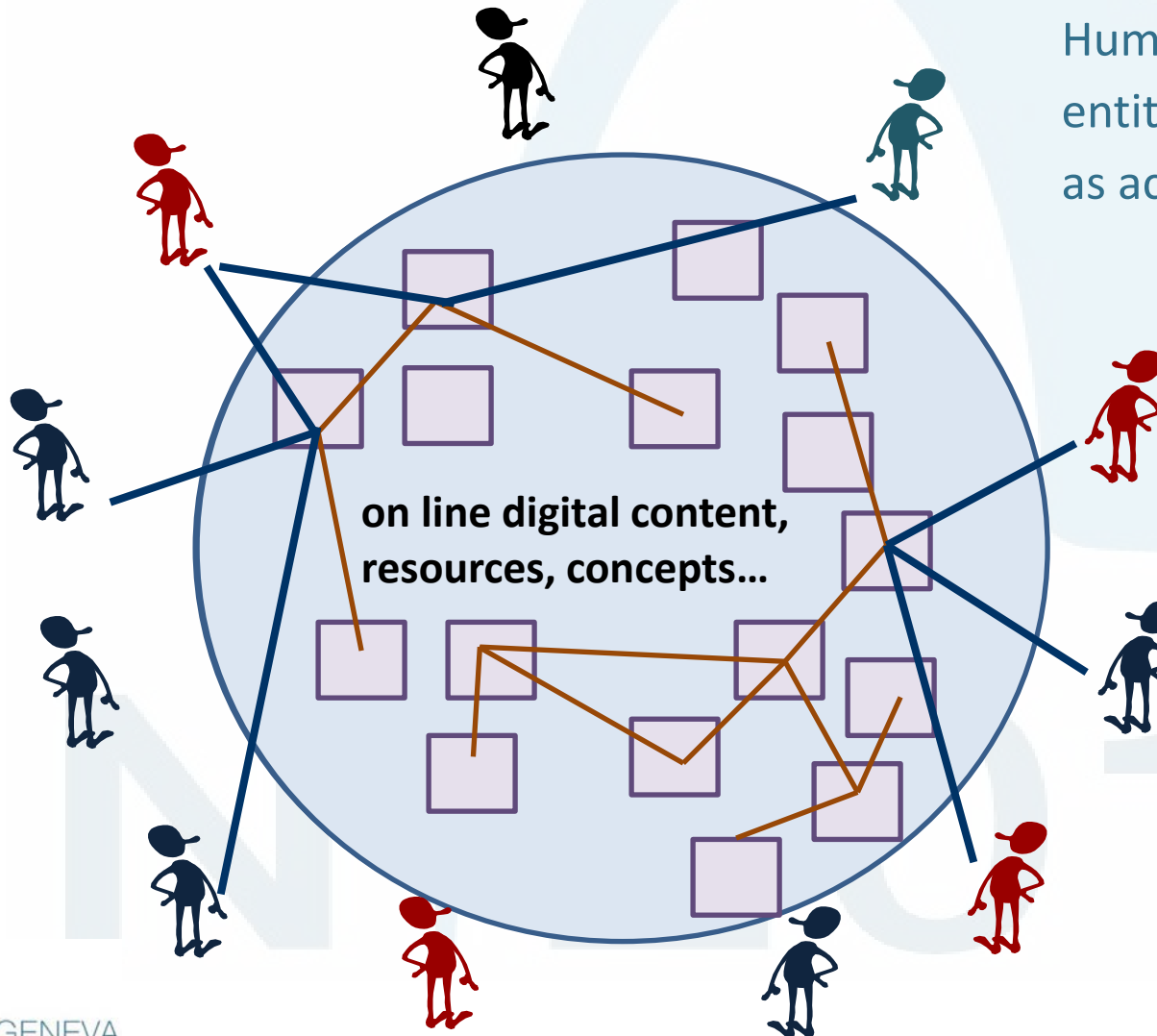
ResearchGate

Academia

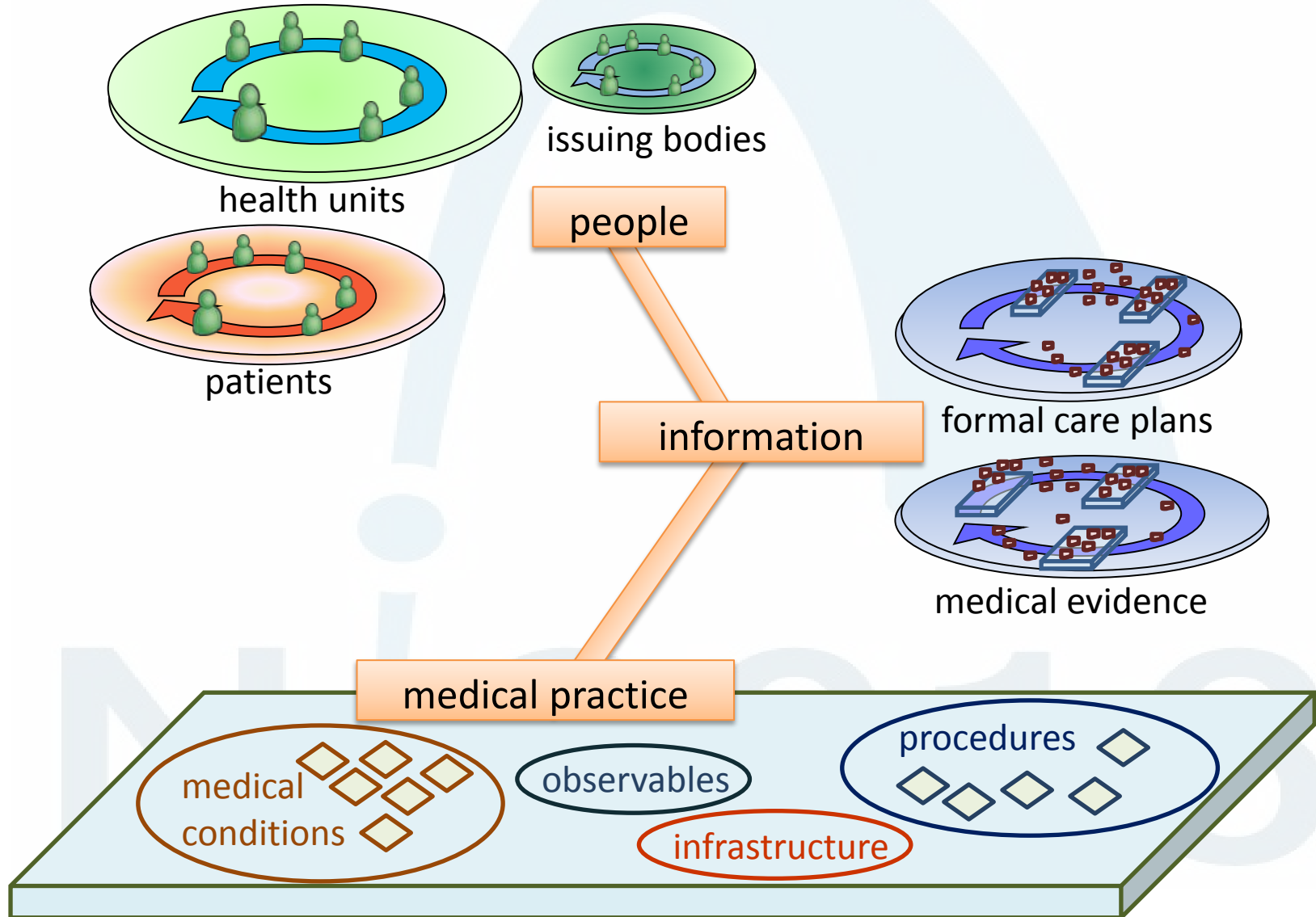
PatientsLikeMe

# Heterogeneous social networks

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



# e-ClinPro heterogeneous network

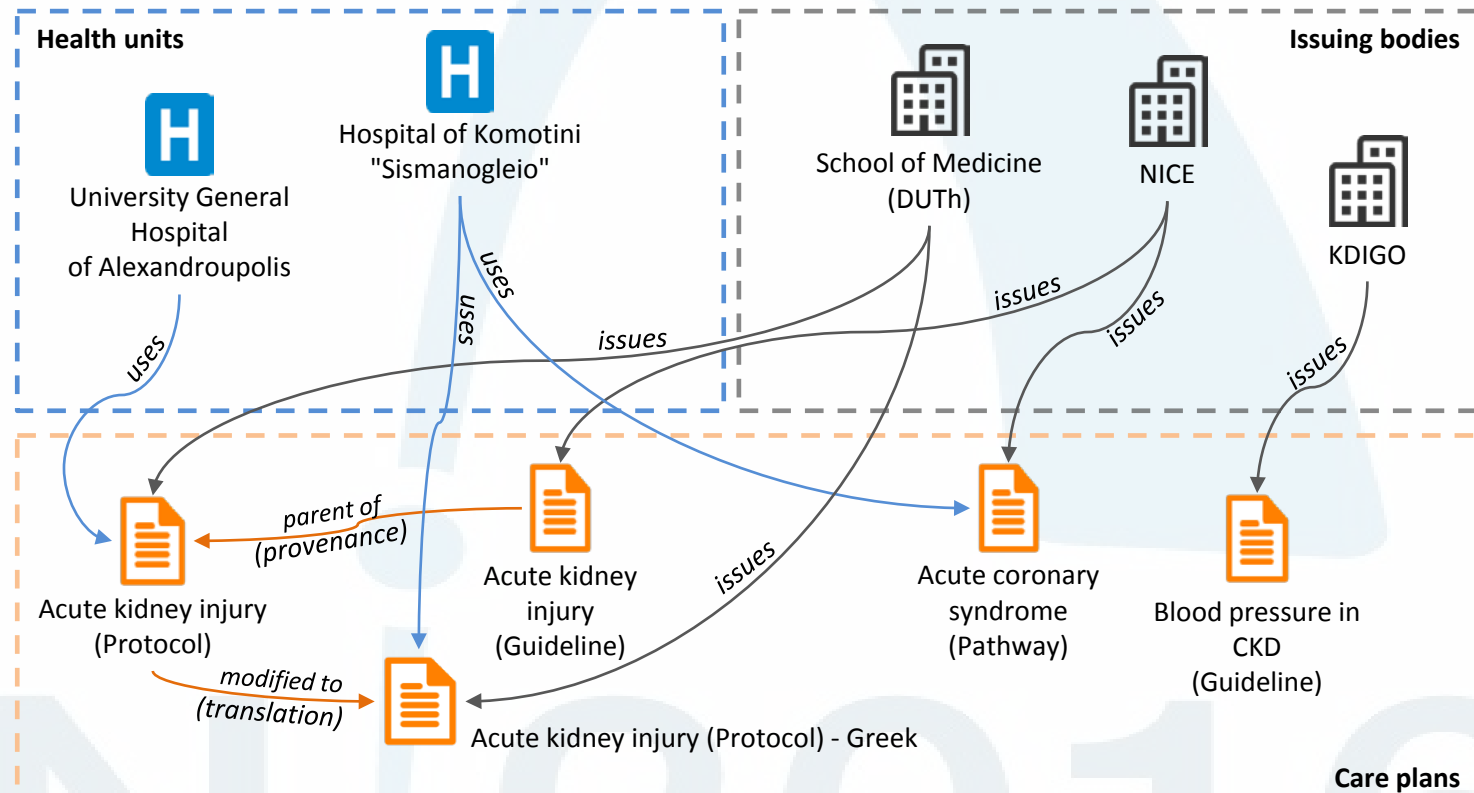




# Clinical protocol provenance, evolution and modification

- **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



# Semantic tagging and interlinking

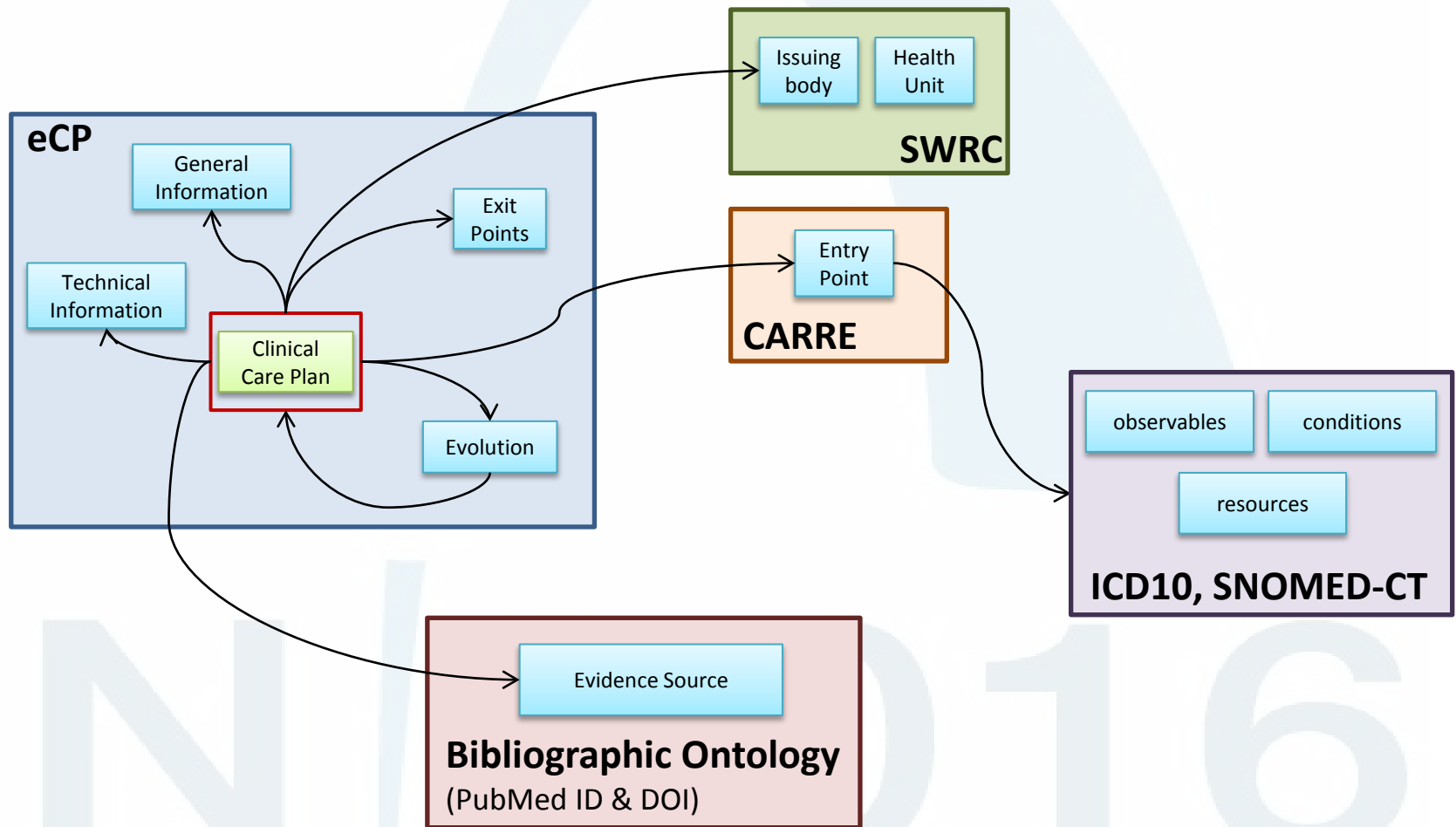
- Profile of clinical protocol based on the **eCP** ontology<sup>1</sup>
- Entry point: observables and observable condition described via the **CARRE** ontology<sup>2</sup>
- Issuing bodies and healthcare units are described following the **SWRC** ontology<sup>3</sup>
- Semantic tagging of medical terms with external resources via **ICD-10** and **SNOMED**
- Medical evidence description based on the Bibliographic Ontology (via **PubMed** identifier and **DOI**)

<sup>1</sup>Kaldoudi, E., Drosatos, G., Portokallidis, 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.

<sup>2</sup>Third, A., Kaldoudi, E., Gotsis, G., Roumeliotis, S., Pafili, K. and Domingue, J., 2015. **Capturing scientific knowledge on medical risk factors**. In K-CAP2015: 8th International Conference on Knowledge Capture. ACM.

<sup>3</sup>Sure, Y., Bloehdorn, S., Haase, P., Hartmann, J. and Oberle, D., 2005. **The SWRC ontology—semantic web for research communities**. In Portuguese Conference on Artificial Intelligence (pp. 218-231). Springer Berlin Heidelberg.

# Semantic tagging and interlinking



## E-CLINPRO: IMPLEMENTATION

# e-ClinPro implementation

- **Backend**

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

- **Frontend**

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

- **Integration with**

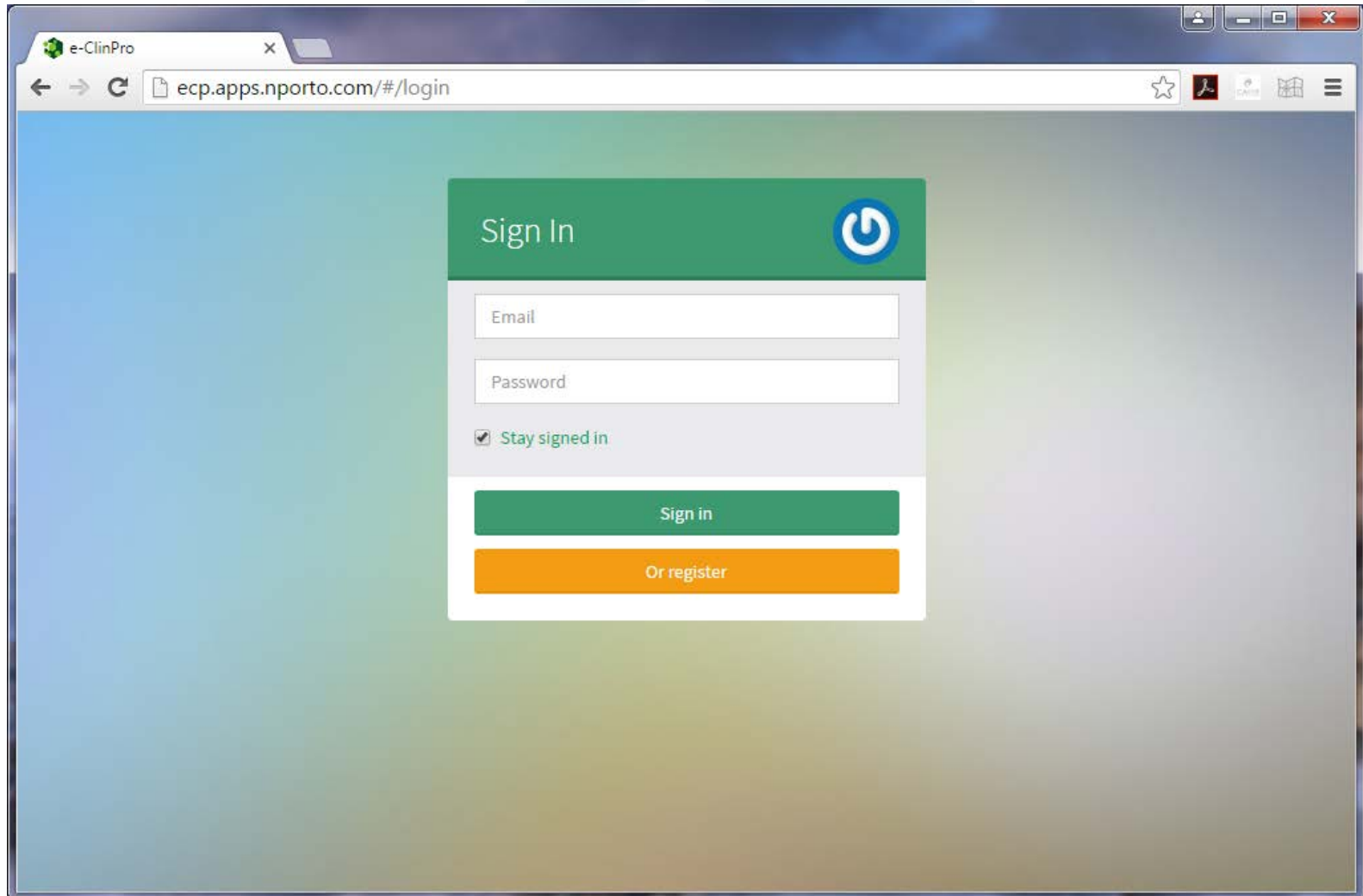
- NCBO **BioPortal** API
- **PubMed** API

- **Available online in:**

<http://iris.med.duth.gr/research/ecp>

The screenshot displays the e-ClinPro web application. The top navigation bar includes the 'e-ClinPro' logo, a menu icon, and a 'Guest' user profile. The main content area is titled 'Protocols' with a subtitle 'Manage your protocols here!' and an 'Add New Protocol' button. A specific protocol, 'Acute coronary syndrome', is selected, showing a breadcrumb trail and edit/delete icons. The protocol details are organized into sections: 'Management pathway' (containing 'Related Conditions' like Acute coronary syndrome, Stable angina, Myocardial infarction, Chest pain, and Hyperglycaemia, unspecified), 'Downloads & links' (providing a URL to the NICE pathway overview), 'Entry points' (highlighted with an orange box and containing the logic 'Chest pain [x] yes AND ( Assessment of chest pain [x] stable OR Assessment of chest pain [x] unstable )'), 'Description' (stating the pathway covers the assessment and diagnosis of recent onset chest pain), and 'Evidence list' (citing NICE guidance and a study on Unstable Angina and NSTEMI). A detailed view of the 'Entry points' logic is shown in an inset, illustrating the use of 'AND', 'OR', and 'value of' operators to combine conditions like 'Chest pain' and 'Assessment of chest pain' with values 'yes', 'stable', and 'unstable'.

# E-ClinPro: Login



The screenshot shows a web browser window with the address bar displaying `ecp.apps.nporto.com/#/login`. The page features a central login form with a green header bar containing the text "Sign In" and a power button icon. Below the header, there are two input fields for "Email" and "Password". A checkbox labeled "Stay signed in" is checked. At the bottom of the form, there are two buttons: a green "Sign in" button and an orange "Or register" button.

Sign In

Email

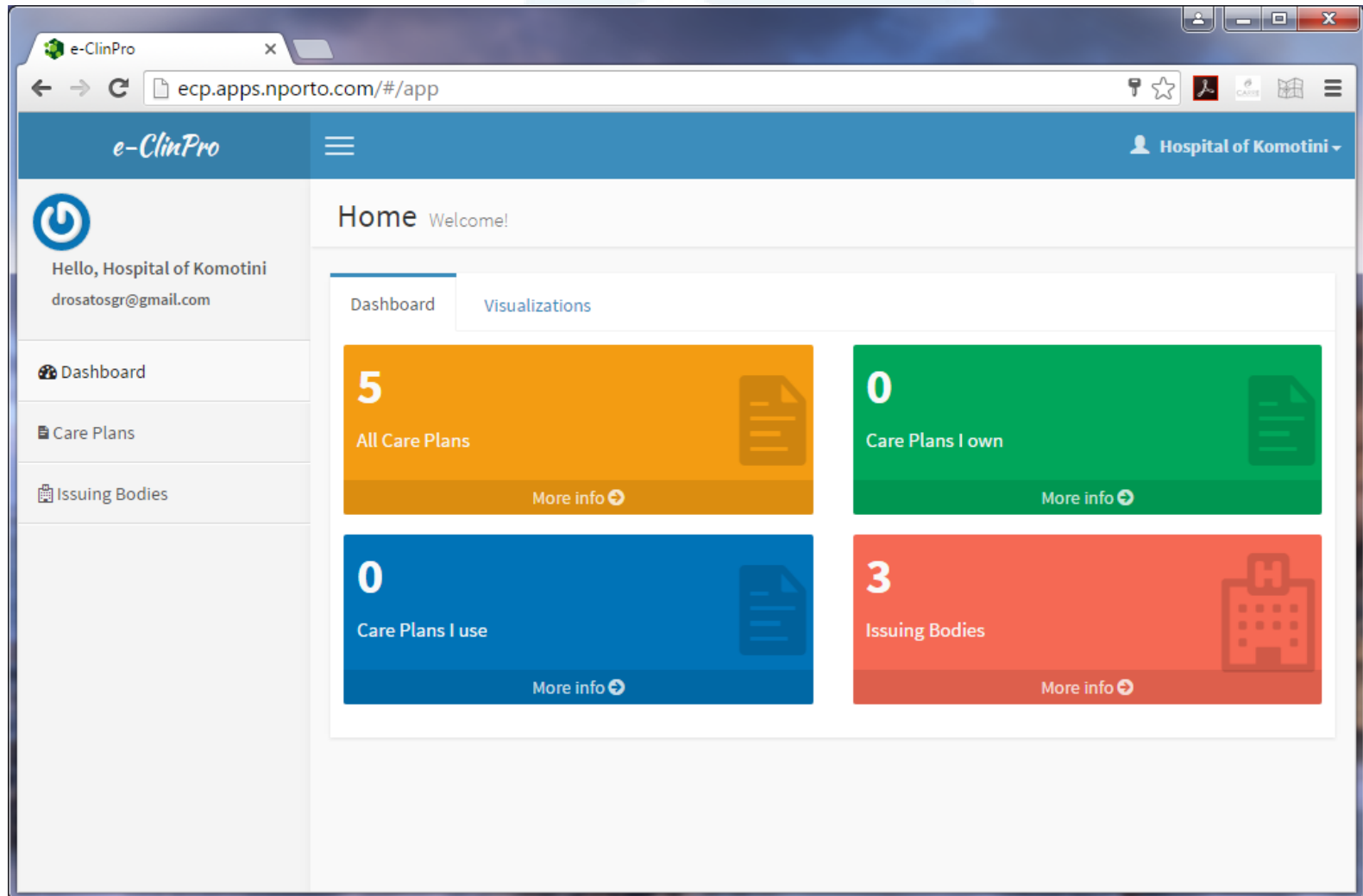
Password

☒ Stay signed in

Sign in

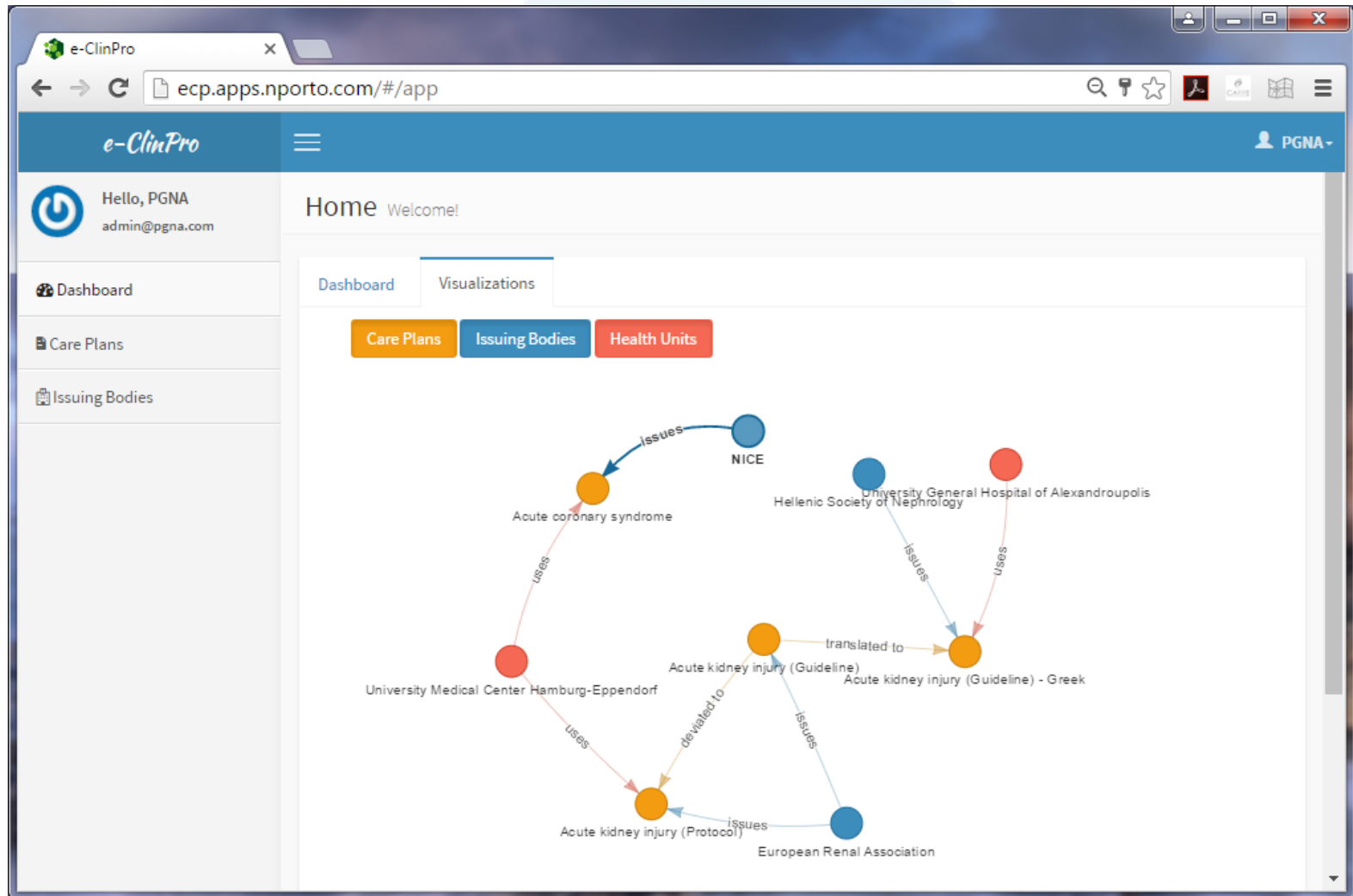
Or register

# E-ClinPro: Dashboard





# E-ClinPro: Visualizations



# E-ClinPro: Care plans list

The screenshot displays the E-ClinPro web application interface. The browser address bar shows the URL `ecp.apps.nporto.com/#/protocols`. The application header includes the **e-ClinPro** logo, a user greeting "Hello, Hospital of Komotini" with the email `drosatosgr@gmail.com`, and a navigation menu with options: **Dashboard**, **Care Plans**, and **Issuing Bodies**. The main content area is titled "Care Plans" with the subtitle "Manage your protocols here!". It features a search bar labeled "Find protocols" and filter buttons for "All", "Own", and "Used". A button "Add New Care Plan" is located in the top right corner. The list of care plans includes:

- Helicobacter pylori**
  - Diagnostic guideline**
    - [Helicobacter pylori](#)
    - [Dyspepsia](#)
  - Entry points**

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

[Dyspepsia](#) ☐ diagnosed AND ( [Melena](#) ☐ diagnosed OR
- 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 )
- 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](#)

# E-ClinPro: Care plan profile

The screenshot displays the E-ClinPro web application interface. The browser address bar shows the URL `ecp.apps.nporto.com/#/protocols/56017105819a2f0300bfda1e`. The application header includes the *e-ClinPro* logo, a menu icon, and the user's institution, **Hospital of Komotini**.

The left sidebar contains a user profile section with a power icon, the text "Hello, Hospital of Komotini", and the email `drosatosgr@gmail.com`. Below this are navigation links for **Dashboard**, **Care Plans**, and **Issuing Bodies**.

The main content area is titled **Acute kidney injury**. It contains the following sections:

- Description:** The kidneys clean the blood by removing waste products. Many different conditions can lead to the ki... [More](#)
- Genre:** Guideline
- Type:** Management
- Related Health Issues:**
  - Acute nontraumatic kidney injury
- Sources:**
  - url: <https://www.nice.org.uk/guidan...>
- Entry points:**

(( Serum creatine kinase measurement  $\geq$  300% of baseline OR Serum creatine kinase measurement  $\geq$  0.4 mg/dL) AND ( Urine  $\leq$  0.3 mL/kg/hr OR Urine  $\leq$  100 mL/24h) ) OR acute kidney injury diagnosis  $\geq$  severe
- Exit points:**
- Issuing Body:** NICE
- Evidence sources:**

# E-ClinPro: Edit care plan

e-ClinPro

ecp.apps.nporto.com/#/protocols/56017105819a2f0300bfda1e/edit

Hello, PGNA  
admin@pgna.com

Dashboard

Care Plans

Issuing Bodies

Edit Care Plan [Export to XML](#)

General Source **Evidence references** Entry/Exit Points Required resources

**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, Fluck N, Black C. ©2015

[Submit](#)

# E-ClinPro: Initial condition builder

e-ClinPro

ecp.apps.nporto.com/#/protocols/56017105819a2f0300bfda1e/edit

e-ClinPro PGNA

Entry Points

User friendly output:

( ( Serum creatine kinase measurement > 300% of baseline OR Serum creatine kinase measurement > 0.4 mg/dL ) AND ( Urine < 0.3 mL/kg/hr OR Urine < 100 mL/24h ) ) OR acute kidney injury diagnosis = severe

OR Add Condition Add Group Remove Group

AND Add Condition Add Group Remove Group

AND Add Condition Add Group Remove Group

OR Add Condition Add Group Remove Group

not Serum creatine kinase measurement value > 300% of baseline

OR

not Serum creatine kinase measurement value > 0.4 mg/dL

AND

OR Add Condition Add Group Remove Group

not Urine value < 0.3 mL/kg/hr

## CONCLUSION

Ni2016

# 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.