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# An Approach to Decision Support in Heart Failure

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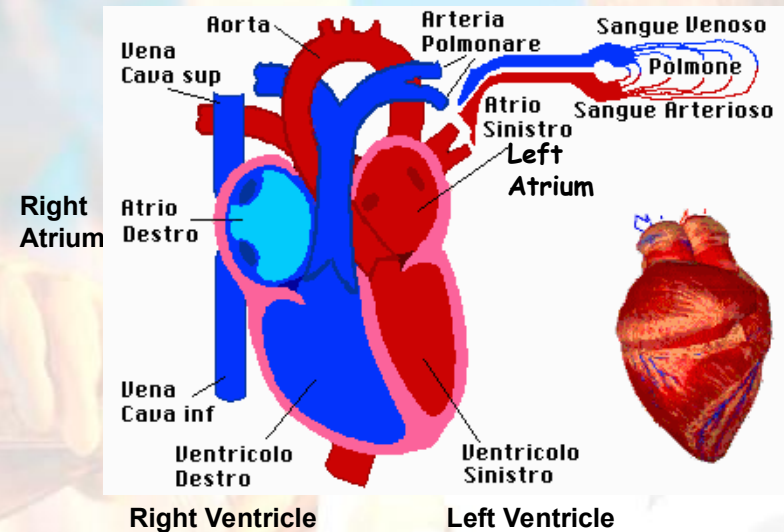
# Heart Failure (HF)

Have you an idea what does **1%** of reduction of heart failure cases could be?

In Europe each year:

**1.500.000 death**

**14.000.000 heart decompensation cases**



One of **main relevant causes of death & health problem** in western civilized countries complex clinical syndrome:

- Heart no more able to contract & to pump blood to circulatory system
- body accumulates water, any action cause fatigue ...

Social & economic **strong impact**

- hospital days to spend, different life style to conduct, time & money wasted



# HEARTFAID



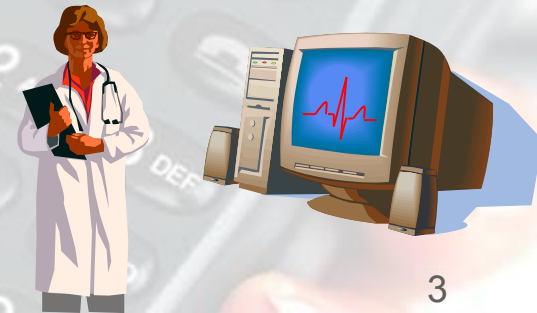
● *“A knowledge based platform of services for supporting medical-clinical management of the heart failure within the elderly population”*

aims

- Improve life quality
- reduce hospital admissions
- allow to provide most of controls at home

● **also**

- Improve clinical status
- support difficult diagnosis, follow-up, and prognosis



# Clinical Decision Support Systems (CDSS)

- **Early 1960s:** computerized applications development to support health care **started**



- **Most common realizations:**

- electronic medical record (information retrieval)
- computerized alerts & reminders
- clinical guidelines formalizations
- diagnostic support

- **CDSS development primary task: representing human knowledge**

- formalize knowledge
- solve problems
- derive other knowledge
- planning future activities

- **Representing knowledge**

- KB is rule/frame/network/logic based
- Workflow based representation also well-known (guidelines modelling)

# Clinical Decision Support Systems & Semantic Web Technologies (SWT)

- Semantic Web Technologies gather attention within CDSS for

- data integration
- knowledge representation
- reasoning

- SWT use evidence :

- rise of several ontology (like) formalizations of medical domain, e.g.:

- Systematized Nomenclature of Medicine (SNOMED)
- Unified Medical Language System (UMLS)
- Medical Subject Heading (MeSH)
- GuideLine Interchange Format (GLIF)

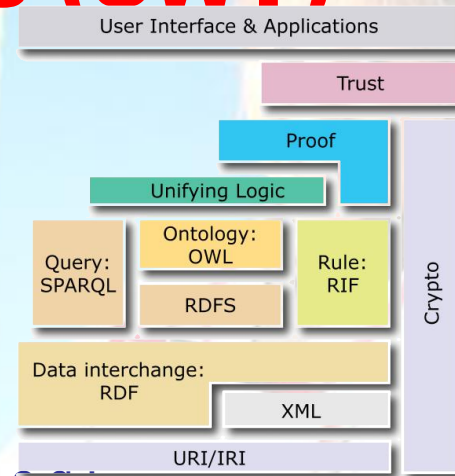
- systems developed using SWT, e.g.:

- decision support in breast cancer management
- clinical practice guidelines modelling

- W3C itself involved:

- Health Care and Life Sciences group
- RIF working group debated a medical use case

- SW recommendation insufficient to solve all problems  
ad hoc strategy usually developed



# Knowledge Domain Sharing

The meaning of X is  
Y

Illogical !

I want to say the last  
word!

## Difficulties:

Communication of models and concepts

Deciding on the required level of detail

# Knowledge Domain Formalization

- **European Guidelines: written by/for clinicians**



...

**2 Aetiology of heart failure in Europe**

Chronic heart failure may be due to myocardial dysfunction (in a vast majority of subjects caused by ischaemic heart disease or arterial hypertension, more rarely by other primary or secondary cardiomyopathies),

...

- **Developing an ontology through**

- Discussion with experts
- Extraction of terms from texts & articles & existing ontologies

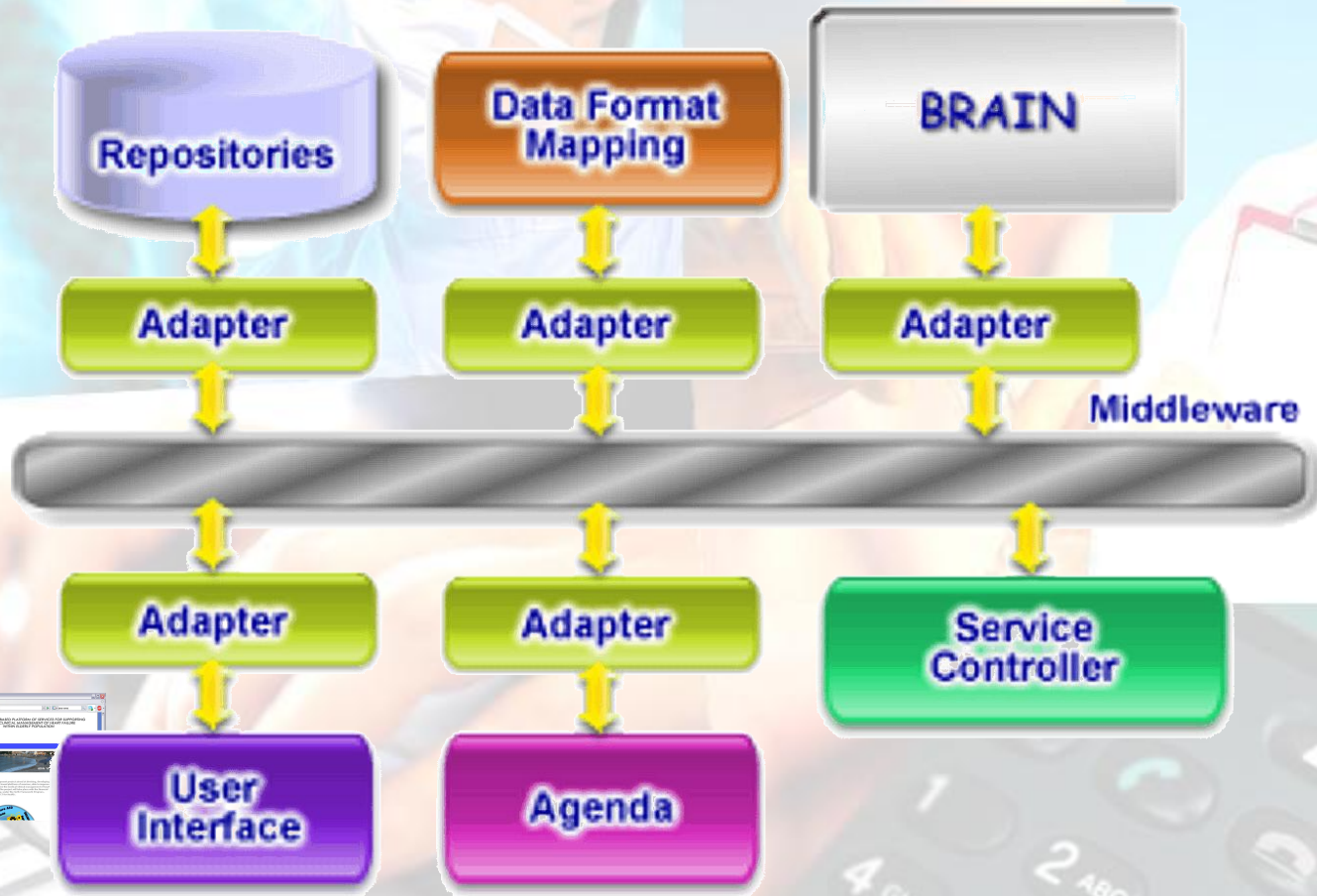


# State of the Art Investigation Main Platform Technologies

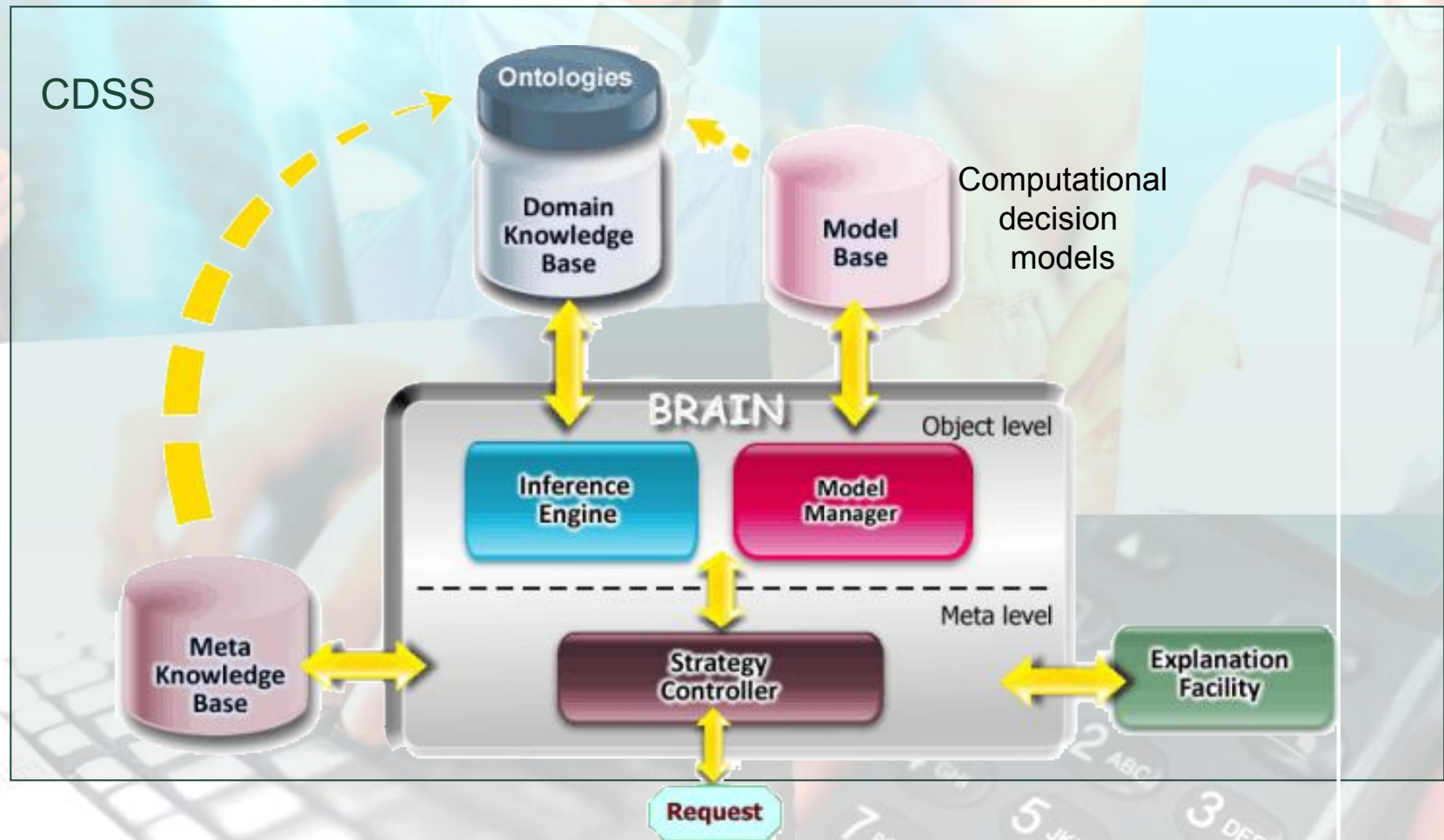




# HEARTFAID Platform: General View



# HEARTFAID Platform: The CDSS Brain Architecture



# Brain: Implementation Tools

## ● Inference Engine:

- Swoop+Protege
- Jena + ARQ
- Pellet

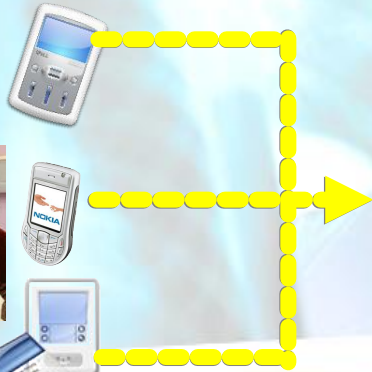
## ● Other Models

- SVM, Bayesian Networks, Neural Networks

# System Implementation: Real Use Case

## HEARTFAID Platform

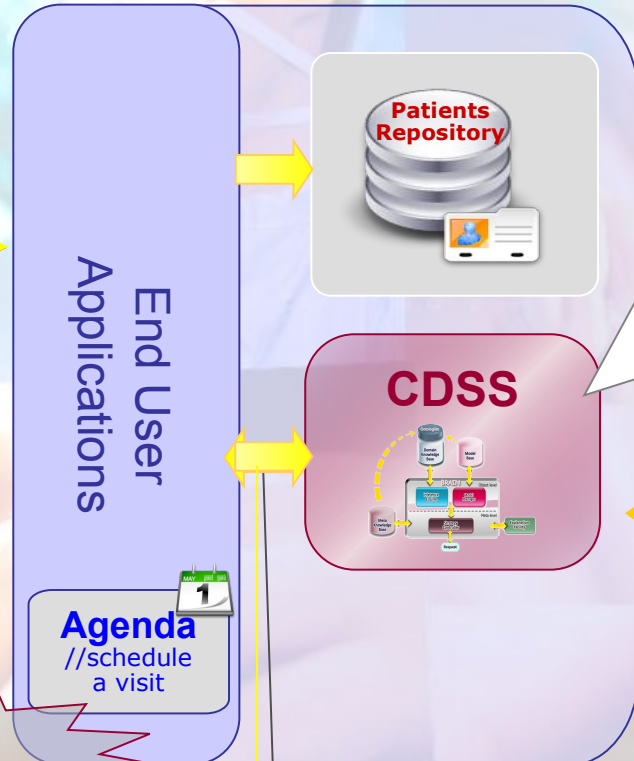
### Telemonitoring



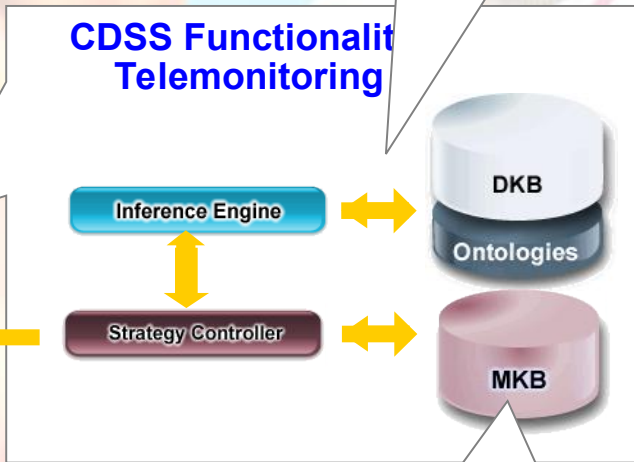
Minnesota Questionnaire



devices



**Inference on patient's data**  
 Ischemic Cardiomiopathy + marked activity limitation  
 → Alert: A1, Priority: P5



### CDSS Functionality Telemonitoring

**Visit Scheduled**

**Request: Interpret new data**  
 •Priority: P5



**Strategy: Trigger Inference Engine**  
`call(InfEng(telemon, P,data_KB);`  
 ...

# Shortened

- Visit performed
- Signs & Symptoms collected
- CDSS suggested to perform EcoCardioGram
- ECO is performed
- CDSS analyze all infos & suggests therapy change

# At Home (Telemonitoring)

HEARTFAID:: Patient Minnesota Questionnaire - Mozilla Firefox

File Modifica Visualizza Cronologia Segnalibri Strumenti ?

http://www.heartfaid.org:8080/Heartfaid/servlet/Controller



## Minnesota Questionnaire

The following questions ask how much your heart failure (heart condition) affected your life during the past month (4 weeks). After each question, choose the 0, 1, 2, 3, 4 or 5 to show how much your life was affected. If a question does not apply to you, choose the 0 after that question.

Did your heart failure prevent you from living as you wanted during the past month (4 weeks) by		0=No 1=Very Little ----- 5=Very Much
1	causing swelling in your ankles or legs?	(0 <input type="radio"/> ) - (1 <input type="radio"/> ) - (2 <input type="radio"/> ) - (3 <input type="radio"/> ) - (4 <input type="radio"/> ) - (5 <input type="radio"/> )
2	making you sit or lie down to rest during the day?	(0 <input type="radio"/> ) - (1 <input type="radio"/> ) - (2 <input type="radio"/> ) - (3 <input type="radio"/> ) - (4 <input type="radio"/> ) - (5 <input type="radio"/> )
3	making your walking about or climbing stairs difficult?	(0 <input type="radio"/> ) - (1 <input type="radio"/> ) - (2 <input type="radio"/> ) - (3 <input type="radio"/> ) - (4 <input type="radio"/> ) - (5 <input type="radio"/> )
4	making your working around the house or yard difficult?	(0 <input type="radio"/> ) - (1 <input type="radio"/> ) - (2 <input type="radio"/> ) - (3 <input type="radio"/> ) - (4 <input type="radio"/> ) - (5 <input type="radio"/> )
5	making your going places away from home difficult?	(0 <input type="radio"/> ) - (1 <input type="radio"/> ) - (2 <input type="radio"/> ) - (3 <input type="radio"/> ) - (4 <input type="radio"/> ) - (5 <input type="radio"/> )
6	making your sleeping well at night difficult?	(0 <input type="radio"/> ) - (1 <input type="radio"/> ) - (2 <input type="radio"/> ) - (3 <input type="radio"/> ) - (4 <input type="radio"/> ) - (5 <input type="radio"/> )
7	making your relating to or doing things with your friends or family difficult?	(0 <input type="radio"/> ) - (1 <input type="radio"/> ) - (2 <input type="radio"/> ) - (3 <input type="radio"/> ) - (4 <input type="radio"/> ) - (5 <input type="radio"/> )
8	making your working to earn a living difficult?	(0 <input type="radio"/> ) - (1 <input type="radio"/> ) - (2 <input type="radio"/> ) - (3 <input type="radio"/> ) - (4 <input type="radio"/> ) - (5 <input type="radio"/> )
9	making your recreational pastimes, sports or hobbies difficult?	(0 <input type="radio"/> ) - (1 <input type="radio"/> ) - (2 <input type="radio"/> ) - (3 <input type="radio"/> ) - (4 <input type="radio"/> ) - (5 <input type="radio"/> )
10	making your sexual activities difficult?	(0 <input type="radio"/> ) - (1 <input type="radio"/> ) - (2 <input type="radio"/> ) - (3 <input type="radio"/> ) - (4 <input type="radio"/> ) - (5 <input type="radio"/> )
11	making you eat less of the foods you like?	(0 <input type="radio"/> ) - (1 <input type="radio"/> ) - (2 <input type="radio"/> ) - (3 <input type="radio"/> ) - (4 <input type="radio"/> ) - (5 <input type="radio"/> )
12	making you short of breath?	(0 <input type="radio"/> ) - (1 <input type="radio"/> ) - (2 <input type="radio"/> ) - (3 <input type="radio"/> ) - (4 <input type="radio"/> ) - (5 <input type="radio"/> )
13	making you tired, fatigued, or low on energy?	(0 <input type="radio"/> ) - (1 <input type="radio"/> ) - (2 <input type="radio"/> ) - (3 <input type="radio"/> ) - (4 <input type="radio"/> ) - (5 <input type="radio"/> )
14	making you stay in a hospital?	(0 <input type="radio"/> ) - (1 <input type="radio"/> ) - (2 <input type="radio"/> ) - (3 <input type="radio"/> ) - (4 <input type="radio"/> ) - (5 <input type="radio"/> )



devices

# Clinician On Duty



HEARTFAID:: Patients Monitor - Mozilla Firefox

File Modifica Visualizza Cronologia Segnalibri Strumenti ?

http://www.heartfaid.org:8080/Heartfaid/servlet/Controller

## Patients Monitor

id	name	NYHA	status	date/time
1	<input checked="" type="radio"/> Pietro Guarneri	IV	worse	8/11/2007 11:35:25
2	<input type="radio"/> Vito Gattuso	IV	stable	8/11/2007 12:24:30
3	<input type="radio"/> Maria Cecchi	III	worse	8/11/2007 12:15:11
4	<input type="radio"/> Paolo Rossi	II	better	8/11/2007 11:44:14
5	<input type="radio"/> Giovanni Sereni I		better	8/11/2007 10:22:53

### Context links

- detail patient
- schedule visit
- assign therapy



HEARTFAID:: Patient Situation - Mozilla Firefox

http://www.heartfaid.org:8080/Heartfaid/servlet/Controller

## Patient Situation

**Patient Anamnesis**

Name: Pietro

Surname: Guarnieri

Age: 65

Sex: M

Other: former\_smoker

**Patient Status**

NYHA Class: IV

**Diagnostic Procedures**

**Minnesota Questionnaire**

Total Score: 33

Physical Score: 17

Emotional Score: 16

**Trans Thoracic Ecocardiography**

Lvzf: 40%

Esv: 114 ml

Edv: 190 ml

Sv: 76 ml

Lv: 6 cm

**Pharmacological Therapy**

ACE Inhibitors: Captopril Dose (mg/die): 50 x 3

Sparing\_K Diuretics: Amloride Dose (mg): 12.5

Beta-blockers (mg): Dose (mg):

Aspirin Dose(mg/die):

Statin Dose (mg):

**HRV:SDNN Index**

**Context links**

- schedule visit
- assign therapy
- assign diagnostic proc.
- see agenda
- logout

# Hospital Visit



HEARTFAID:: Clinical Visit :: NYHA Determination - Mozilla Firefox

File Modifica Visualizza Cronologia Segnalibri Strumenti ?

http://www.heartfaid.org:8080/Heartfaid/servlet/Controller



## Clinical Visit: NYHA Determination

Patient name: **Pietro Guarneri** - id: **Patient\_1**

### Minnesota Questionnaire

Score	Base	Previous	Current
Total	33	33	97
Physical	13	13	38
Emotional	10	10	22

### NYHA Classification

Base	Previous	Suggested (TotalScore)
II	II	IV (Physical Score) IV

#### Context links

- [schedule visit](#)
- [assign therapy](#)
- [assign diagnostic proc](#)
- [see agenda](#)

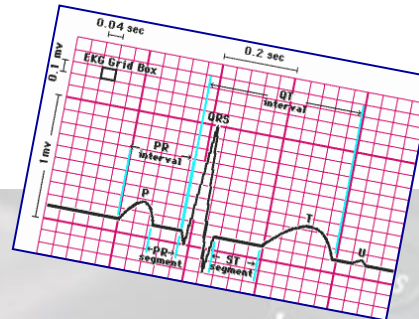
• [logout](#)

Status: *worsening - body water, physical activity, dyspnea, fatigue*

### Decide NYHA classification

set current NYHA to **IV**

Submit Decision

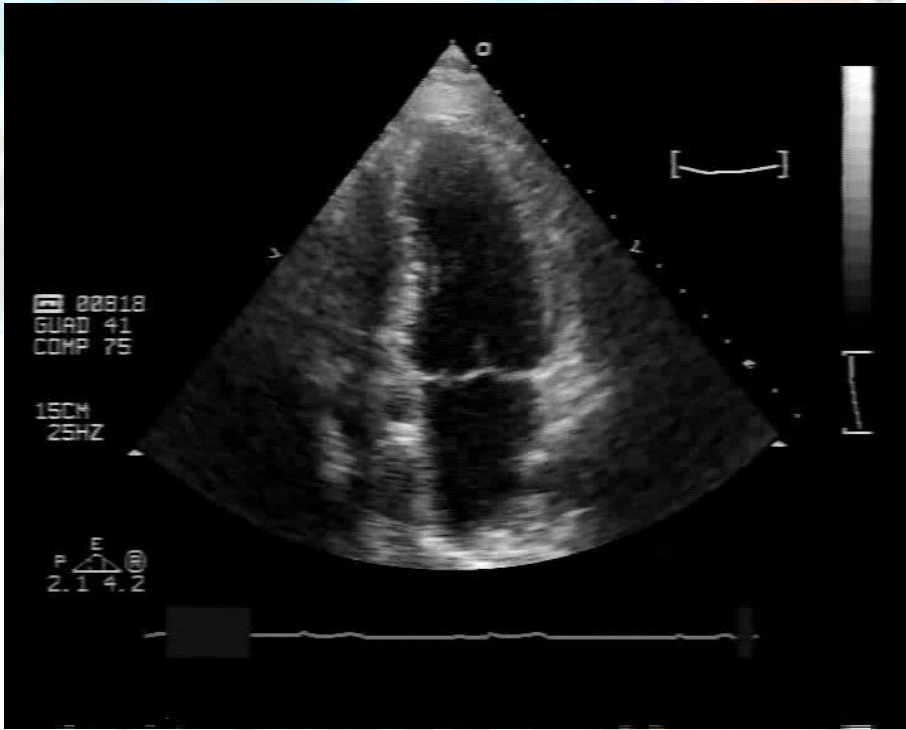


- +HF Signs control
- +ElectroCardioGram
- +EcoCardioGram scheduling

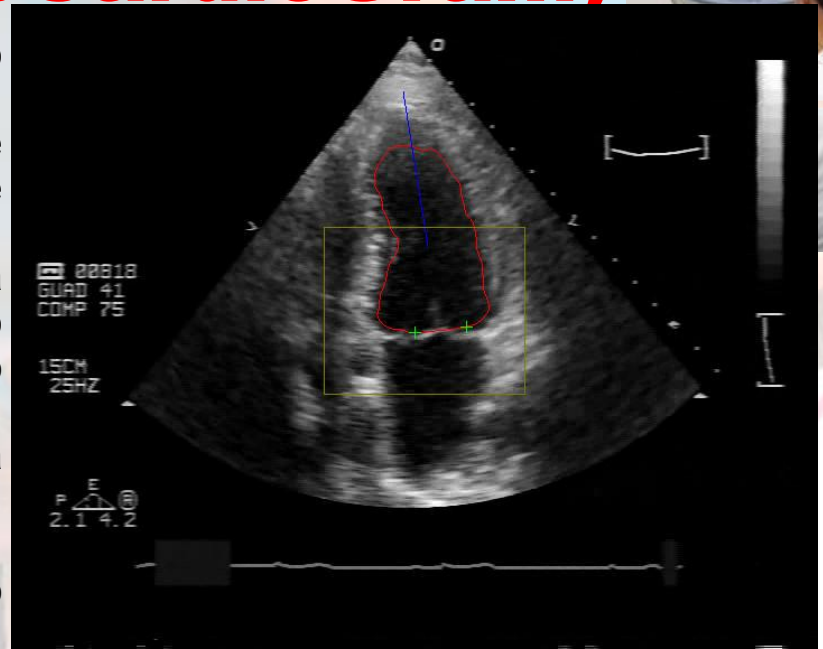


# Sonographer (EcoCardioGram)

original



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Image Processing Algorithms  
Volumes extraction

# Hospital Visit

HEARTFAID: Therapeutic Strategy - Mozilla Firefox


http://www.heartfaid.org:8080/Heartfaid/servlet/Controller

## Therapeutic Strategy

Patient name: **Pietro Guarneri** - id: **Patient\_1**

Type	Medicine	Start Dose	Target	Current	Suggested	Motivation	Choice!
ACEInhibitor	Ramipril	1.25 - 2.5 mg/die	2.5 - 5 2times/die	1.25 mg/die	2.5 mg/die	EF<45, NYHA>0	2.5 mg/die
Beta-blockers	Bisoprololo	1.25mg/die	10mg/die	2.5 mg/die	3.75 mg/die	mono-subminitration	3.75 mg/die
Anti-aldosteronic	Spironolactone	12.5mg/die	50mg/die	12.25 mg/die	25 mg/die	had myocardial infarction, worse symphoms	25 mg/die
Aspirin		100 mg/die	100 mg/die	100 mg/die	100 mg/die	post-ischaemic cardiomyopathy	100 mg/die
Statin	Atorvastatina	10mg/die	40mg/die	10 mg/die	20 mg/die	reduce LDL	20 mg/die
Loop Diuretic	Furosemide	20-40mg/die	100-200mg/die	0	20-40 mg/die	quicker, more effective, filt.glom<30	20-40 mg/die

Add other therapy




**Context links**

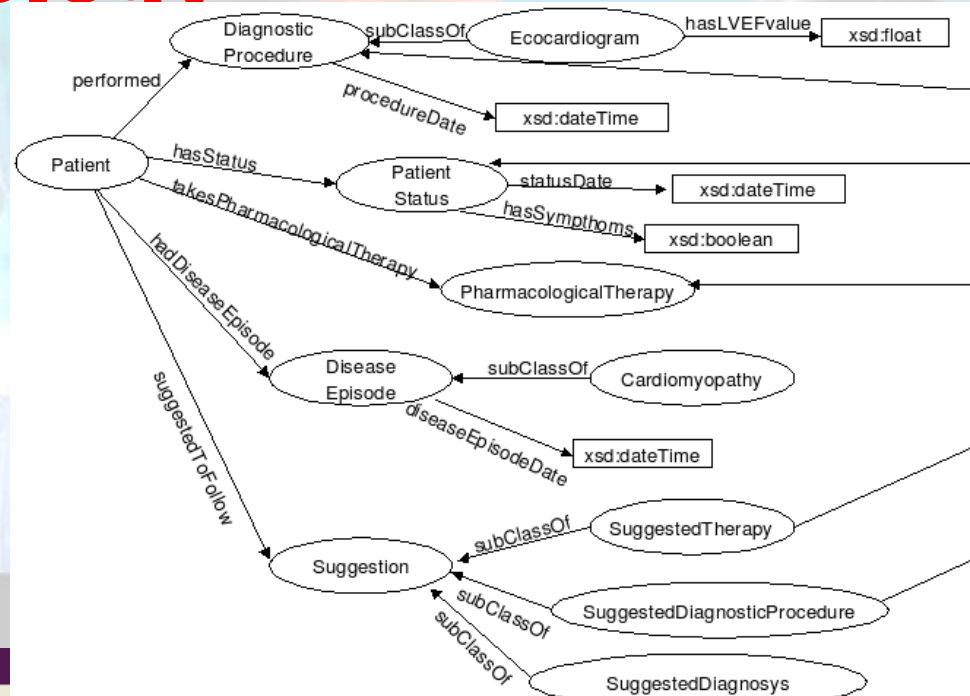
- schedule visit
- assign therapy
- assign diagnostic proc
- see agenda
- [logout](#)

Change of therapeutic strategy decided by clinician supported by CDSS.

# Ontology



Developing several core & upper level ontologies



**CLASS BROWSER**

For Project: ● therapy

**Class Hierarchy**

- ACE\_Inhibitor (5)
- ARB (6)
- Asa (1)
- Beta-blocker (4)
- ▼ ● Diuretic
  - Potassium-sparing\_diuretics
  - Thiazide\_diuretics (4)
  - Loop\_diuretics (3)
- Statin (6)
- Prescription (1)
- ▼ ● Therapy (133)

**INSTANCE BROWSER**

For Class: ● Therapy

Asserted Inferred

**Asserted Instances**

- ◆ Therapy\_Ramipril\_incremental\_dose
- ◆ Therapy\_Ramipril\_incremental\_dose\_2
- ◆ Therapy\_Ramipril\_initial\_dose
- ◆ Therapy\_Ramipril\_target\_dose
- ◆ Therapy\_Rosuvastatina\_incremental

**Asserted Types**

- Therapy

rdfs:comment

**drugDose**

1.25mg 1times/die

**drugName**

◆ Ramipril

# Rules

Elicited from ESC guidelines & strong interaction with clinicians

Example of natural language elicitation

*“If a patient has Left Ventricle Ejection Fraction  $\leq 40\%$  and he is asymptomatic and is assuming ACE Inhibitors and he had a myocardial infarction then a suggestion for the doctor is to give the patient Betablockers”*

The screenshot shows a window titled "SWRL Rule" with a tabbed interface. The "Name" tab is selected, showing the name "Rule- BetaBlockers -LVEF". The "SWRL Rule" tab is also visible, containing the following SWRL rule:

```
performed(?patient, ?diagnosticProcedure) ^
hasLVEFvalue(?diagnosticProcedure, ?lvef_value) ^
swrlb:lessThanOrEqual(?lvef_value, 40) ^
hasStatus(?patient, ?status) ^
symptomatic(?status, true) ^
takesPharmacologicalTherapy(?patient, ACE_inhibitors) ^
hasDiseaseEpisode(?patient, acute_myocardial_infarction)
→ suggestion(?patient, BetaBlockers)
```

Below the rule text is a toolbar with various symbols for logical operations and formatting, including a checkmark icon.

Rules are a strong help to foster collaboration and improve to support decisions

# Conclusions & Future Work

- Approach based on Semantic Web technologies shown
- Current implementation results (finalization in 2009)
- Terminological ontology is the most complete for this problem
- Clinicians collaborating with us glad of preliminary results

## • Future activities:

finalize implementation of the CDSS

- KB
- Model Base algorithms
- Meta level

other platform modules integration



Many thanks  
for  
your attention !

