Health-e-Child

Grid Based Applications in Health-e-Child

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Contents

- Motivation and Clinical Background
- Grid Based Applications in Cardiology
  - Tetralogy of Fallot
  - Data Acquisition
  - Imaging and Simulation
  - Knowledge Discovery and Decision Support

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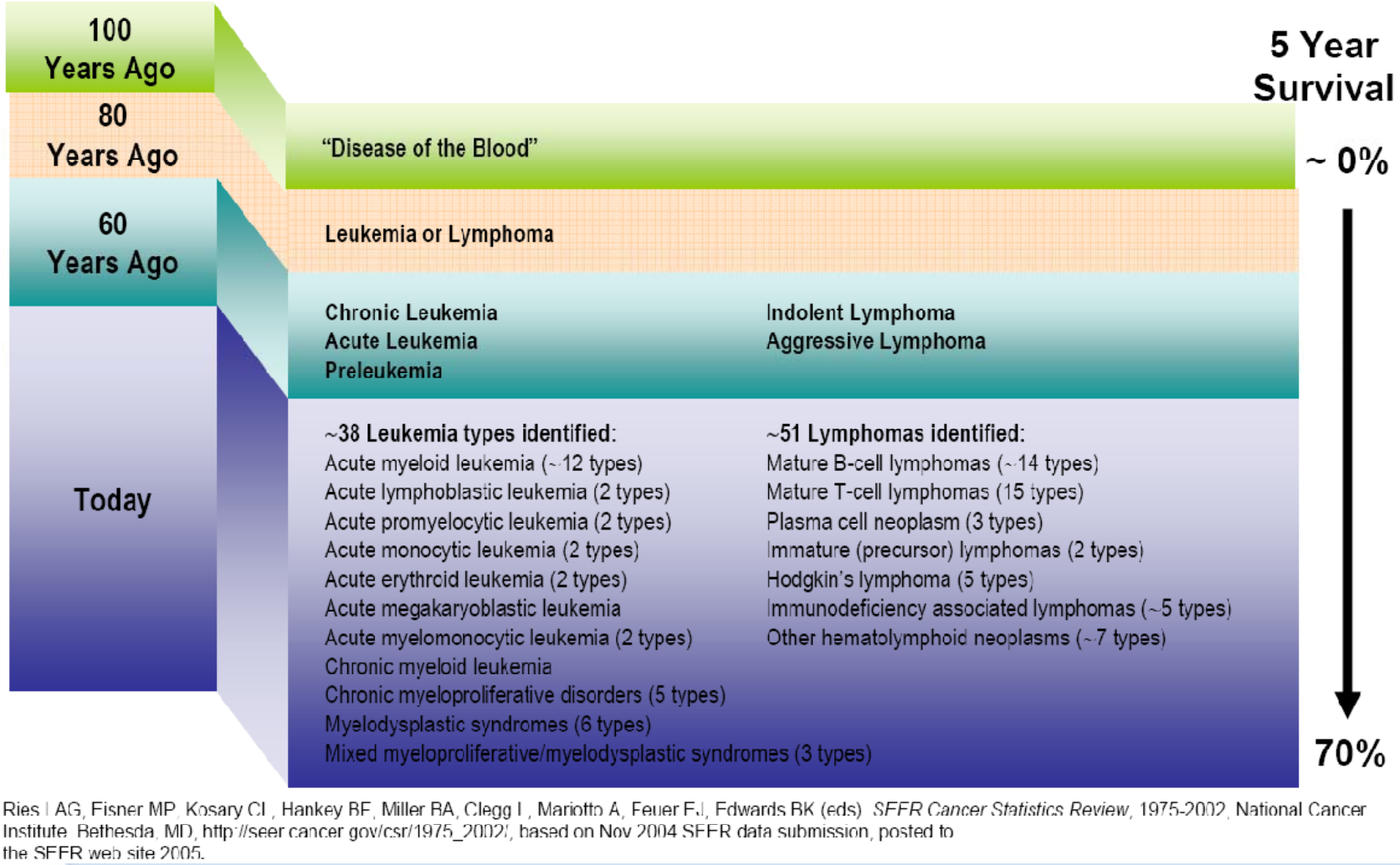
Motivation

- Health-e-Child is about severe, complex paediatric diseases
  - due to **low incidence** only few experts can rely on personal experience for diagnosis and treatment
  - textbook diagnosis may not reflect **latest medical knowledge**
  - cause and/or progression of the **disease are little understood**
  - treatment is severe and **complex** too
  - incentives to **invest** in paediatric research are **low**
- Clinical demand for integration and exploitation of heterogeneous biomedical information
  - vertical dimension – **multiple** traditional and emerging **data** sources
  - horizontal dimension – **multiple sites**
- Need for generic and scalable solutions
  - offer decision support in diagnosis, therapy and follow-up
  - provide complex integrated disease models
  - ubiquitous access to knowledge repositories in clinical routine
  - connect stakeholders in clinical research



Ries LAG, Eisner MP, Kosary CL, Hankey BF, Miller BA, Clegg L, Mariotto A, Feuer EJ, Edwards BK (eds). *SEER Cancer Statistics Review*, 1975-2002, National Cancer Institute. Bethesda, MD, http://seer.cancer.gov/csr/1975_2002/, based on Nov 2004 SEER data submission, posted to the SEER web site 2005.

Health-e-Child
Europe-wide Information Platform for Pediatrics

- Three peadiatric hospitals
  - Gaslini, Genoa, Italy
  - GOSH, London, UK
  - Necker, Paris, France
  - OPBG, Rome, Italy
- Strong interdisciplinary team across
  - Countries and languages
  - Technical and clinical fields
- Research on three peadiatric disease areas:
  - Arthritis
  - Cardiac Disorders
  - Brain Tumours

Research Focus in Rheumatology

Improve current classification of JIA subtypes

- Identify homogeneous groups of clinical features
- Find early predictors of poor outcome
- Identify sensitive markers of joint damage progression

Develop MRI and US paediatric scoring system

- Joint space width varies with age – studies performed on adult are not applicable on children.

Robust Information Fusion

- Pattern discovery in multimodal data, correlation between genomic, clinical and image data

Wrist Hip

Clinical Data
Lab Data, Familial Data
Imaging Data
Wrist & Hip X-Rays
Ultrasound, wrist
Ultrasound, hip
MRI, wrist
MRI, hip
Biological Samples
Blood
Synovial and Serum Levels
Genetic Data

Rely on the collaboration with PRINTO:

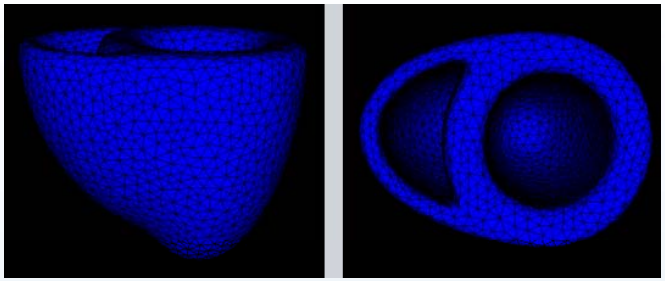
Pediatric **R**heumatology

INternational **T**rials **O**rganization

163 patients enrolled (Target – 300)

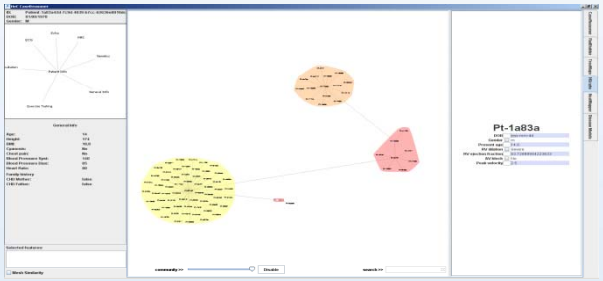
Research Focus in Cardiology

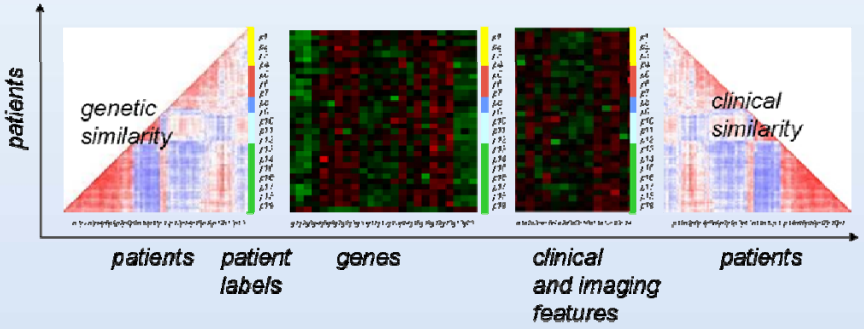
- Concentrating on Right Ventricular Overload and Cardiomyopathies
- Computational electromechanical models of the heart
- RVO monitoring and decision support based on similar cases – similarity search on complex, multimodal data
- Decision Support based on semi-automatic feature extraction from cardiac MR



Long Axis Short Axis

- Health-e-Child CaseReasoner





- Visualizing integrated biomedical data for patient cohorts using treemaps and neighborhood graphs

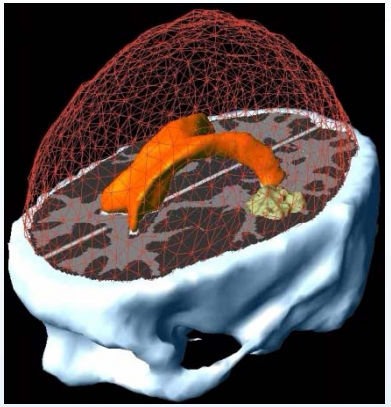
Clinical Data
History
Physical Examination
Exercise Testing
ECG
Imaging Data
Echo 2D/3D
MRI
Genetic DataDNA sequencing, Chromosomal Analysis
Karyotyping
CGH
FISH
Sequencing of 3 candidate genes

257(RVO)+39(CMP) patients enrolled (Target – 300)

Research Focus in Neuro-oncology:

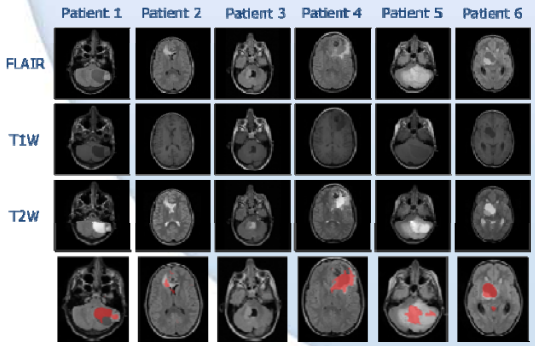
Glioma growth model:

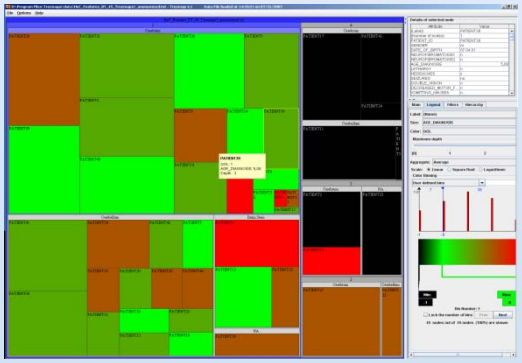
- Interpolating growth between two time instances
- Using proliferation and diffusion of tumor cells
- Including high speed of tumor invasion in white vs. grey matter



Knowledge Discovery, Finding Prognostic Markers:

- Classification of low vs. high grade
- Sub-typing of pilocytic astrocytomas (e.g. regarding tumour site, age)
- Regression analysis of factors (clinical, imaging, genetics) that affect treatment outcome
- Prediction of prognosis (survival rate and quality of life)





Clinical Data
Imaging Data
MRI
Tissue Samples
Tumor Gene Expression Data (Microarray)
Sequence Analysis PTEN, CDKN2A, PTPN11 an
Longitudinal Data (Treatment, Outcome)

49 Studies Collected (Target – 77)

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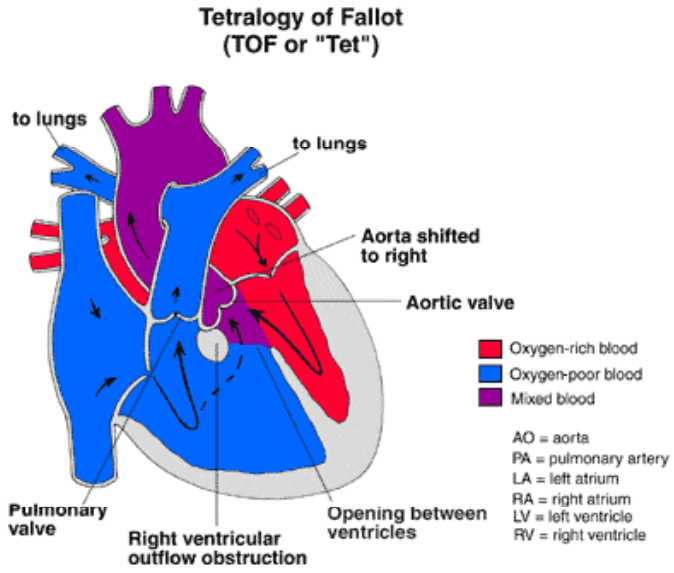
Tetralogy of Fallot

- Complex condition of 4 heart defects:
  - Ventricular septal defect,
  - Pulmonary (or RV outflow tract) obstruction,
  - Overriding aorta and
  - Hypertrophy of RV.
- Requires surgery.
- Occurs in 1 of 2500..20000 live births.



Re-intervention Procedure

- Initial surgery can lead to the destruction of the Pulmonary valve
- This leads to regurgitation of the blood back into the Right Ventricle and loss of function
- When function reaches a certain level (perhaps years after initial surgery), valve implantation is performed
- Percutaneous Pulmonary Valve Implantation (PPVI) is a novel technique to replace the valve without surgery

Melody™ Transcatheter Pulmonary Valve from Medtronic

Research Goal: Predicting the Best Timing for Pulmonary Valve Replacement

- The timing for reintervention and the various surgical reconstruction possibilities of the right-ventricular outflow tract are still controversial and evolving
- Decision when to reintervene depends on many factors
  - Extent of pulmonary regurgitation, residual or recurrent pulmonary stenosis, RV dilation and deterioration of ventricular function
  - Anatomy of RVOT, RVOT aneurysms, potential complications and sequelae
  - Clinical parameters, ECG, exercise testing (e.g. age of patient, prolonged QRS duration)

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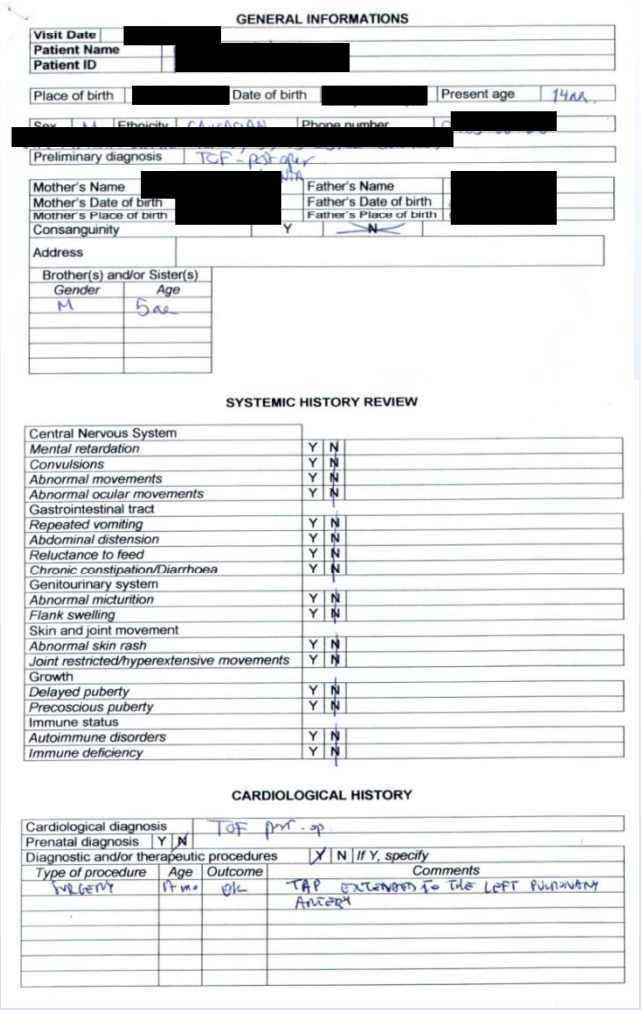
Case History

- 14 yrs old
- Male
- TOF post-op. (1994)
- No medications
- Asymptomatic
- Preserved exercise tolerance



GENERAL INFORMATIONS

Visate Date	[redacted]
Patient Name	[redacted]
Patient ID	
Place of birth	[redacted] Date of birth [redacted] Present age 14AA
Sex M Ethnicity CAUCASIAN Phone number	[redacted]
Preliminary diagnosis	TOF - post-op
Mother's Name	[redacted] Father's Name [redacted]
Mother's Date of birth	Father's Date of birth
Mother's Place of birth	Father's Place of birth
Consanguinity	Y N
Address	

Brother(s) and/or Sister(s)	
Gender	Age
M	5AA

SYSTEMIC HISTORY REVIEW

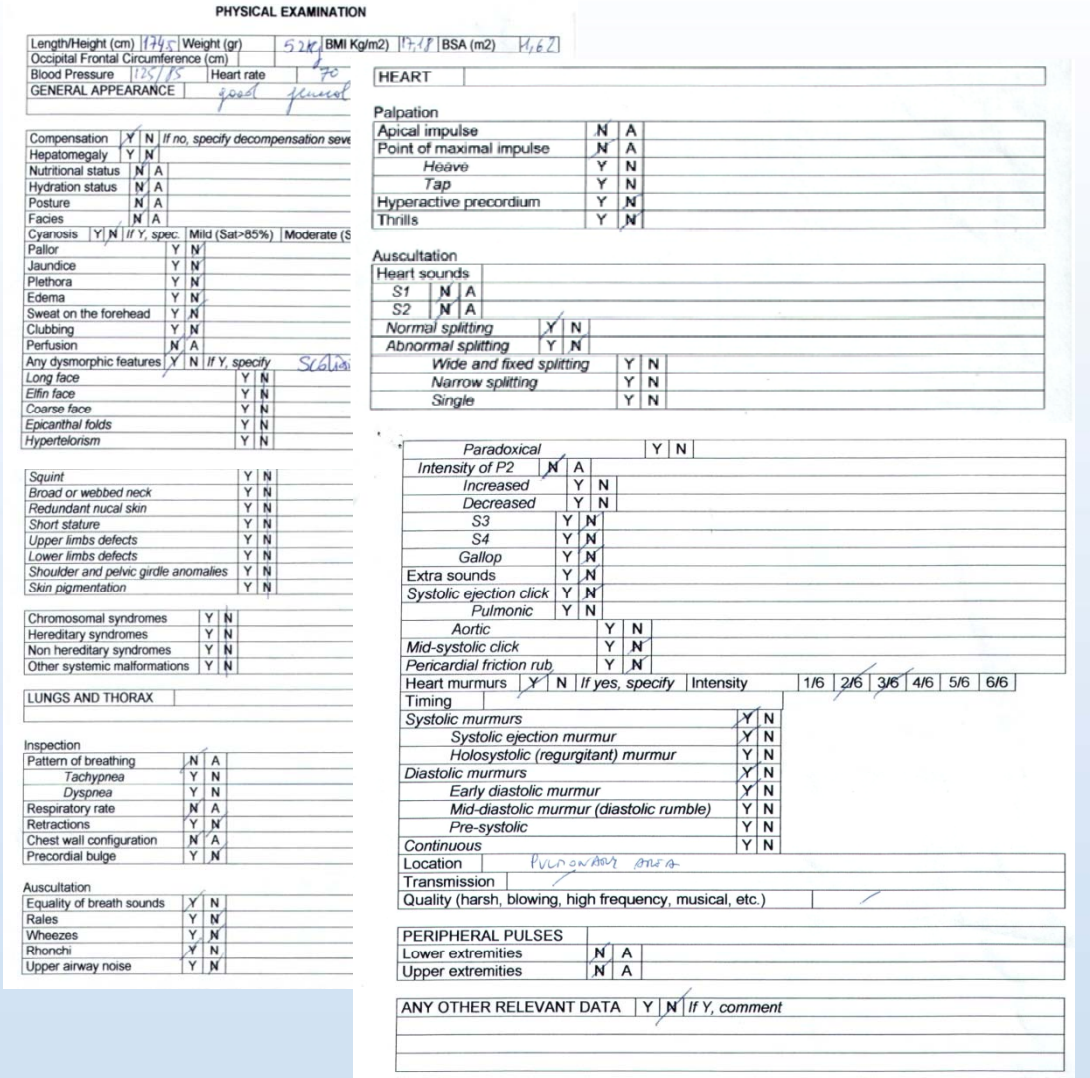
Central Nervous System		
Mental retardation	Y	N
Convulsions	Y	N
Abnormal movements	Y	N
Abnormal ocular movements	Y	N
Gastrointestinal tract		
Repeated vomiting	Y	N
Abdominal distension	Y	N
Reluctance to feed	Y	N
Chronic constipation/Diarrhoea	Y	N
Genitourinary system		
Abnormal micturition	Y	N
Flank swelling	Y	N
Skin and joint movement		
Abnormal skin rash	Y	N
Joint restricted/hyperextensive movements	Y	N
Growth		
Delayed puberty	Y	N
Precocious puberty	Y	N
Immune status		
Autoimmune disorders	Y	N
Immune deficiency	Y	N

CARDIOLOGICAL HISTORY

Cardiological diagnosis	TOF post-op.			
Prenatal diagnosis	Y	N		
Diagnostic and/or therapeutic procedures	Y	N	*If Y, specify*	
Type of procedure	*Age*	*Outcome*	*Comments*	
SURGERY	1 m.o.	O/C	TAP EXTENDED TO THE LEFT PULMONARY ARTERY	

Physical Examination

- 174,5 cm
- 52 Kg
- BMI 17,18
- BSA 1,62 m2
- Good general conditions
- Cardiocirculatory compensation
- BP 125/75 mmHg
- O2 Sat. 99%
- Normal peripheral pulses
- Normal heart sounds
- 2-3/6 systolic ejection murmur +
- diastolic tail



PHYSICAL EXAMINATION

Length/Height (cm)	174,5	Weight (gr)	52K	BMI Kg/m2)	17,18
BSA (m2)	1,62				
Occipital Frontal Circumference (cm)					
Blood Pressure	125/75	Heart rate	70		
GENERAL APPEARANCE	good general				

Compensation	Y	N	If no, specify decompensation seve
Hepatomegaly	Y	N	
Nutritional status	N	A	
Hydration status	N	A	
Posture	N	A	
Facies	N	A	
Cyanosis	Y	N	If Y, spec: Mild (Sat>85%) Moderate (S
Pallor	Y	N	
Jaundice	Y	N	
Plethora	Y	N	
Edema	Y	N	
Sweat on the forehead	Y	N	
Clubbing	Y	N	
Perfusion	N	A	
Any dysmorphic features	Y	N	If Y, specify Scoliosi
Long face	Y	N	
Elfin face	Y	N	
Coarse face	Y	N	
Epicanthal folds	Y	N	
Hypertelorism	Y	N	
Squint	Y	N	
Broad or webbed neck	Y	N	
Redundant nucal skin	Y	N	
Short stature	Y	N	
Upper limbs defects	Y	N	
Lower limbs defects	Y	N	
Shoulder and pelvic girdle anomalies	Y	N	
Skin pigmentation	Y	N	
Chromosomal syndromes	Y	N	
Hereditary syndromes	Y	N	
Non hereditary syndromes	Y	N	
Other systemic malformations	Y	N	

LUNGS AND THORAX

Inspection

Pattern of breathing	N	A
Tachypnea	Y	N
Dyspnea	Y	N
Respiratory rate	N	A
Retractions	Y	N
Chest wall configuration	N	A
Precordial bulge	Y	N

Auscultation

Equality of breath sounds	Y	N
Rales	Y	N
Wheezes	Y	N
Rhonchi	Y	N
Upper airway noise	Y	N

HEART

Palpation

Apical impulse	N	A
Point of maximal impulse	N	A
Heave	Y	N
Tap	Y	N
Hyperactive precordium	Y	N
Thrills	Y	N

Auscultation

Heart sounds		
S1	N	A
S2	N	A
Normal splitting	Y	N
Abnormal splitting	Y	N
Wide and fixed splitting	Y	N
Narrow splitting	Y	N
Single	Y	N
Paradoxical	Y	N
Intensity of P2	N	A
Increased	Y	N
Decreased	Y	N
S3	Y	N
S4	Y	N
Gallop	Y	N
Extra sounds	Y	N
Systolic ejection click	Y	N
Pulmonic	Y	N
Aortic	Y	N
Mid-systolic click	Y	N
Pericardial friction rub	Y	N

Heart murmurs	Y	N	If yes, specify	Intensity	1/6	2/6	3/6	4/6	5/6	6/6
Timing										

Systolic murmurs	Y	N
Systolic ejection murmur	Y	N
Holosystolic (regurgitant) murmur	Y	N
Diastolic murmurs	Y	N
Early diastolic murmur	Y	N
Mid-diastolic murmur (diastolic rumble)	Y	N
Pre-systolic	Y	N
Continuous	Y	N
Location	PULMONARY AREA	
Transmission		
Quality (harsh, blowing, high frequency, musical, etc.)		

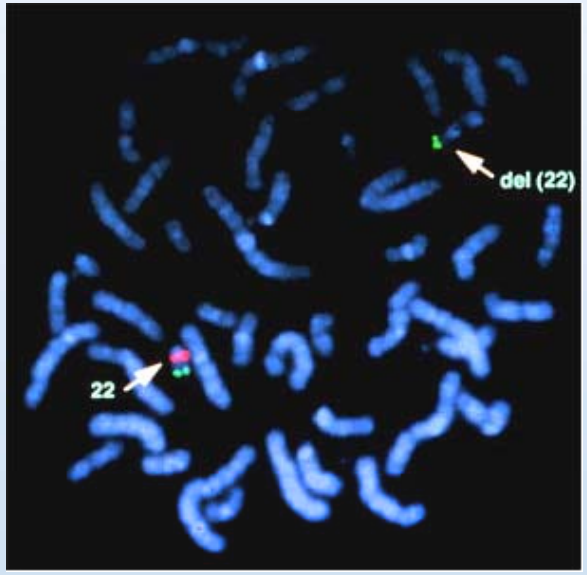
PERIPHERAL PULSES		
Lower extremities	N	A
Upper extremities	N	A

ANY OTHER RELEVANT DATA	Y	N	If Y, comment

Genetic Investigations

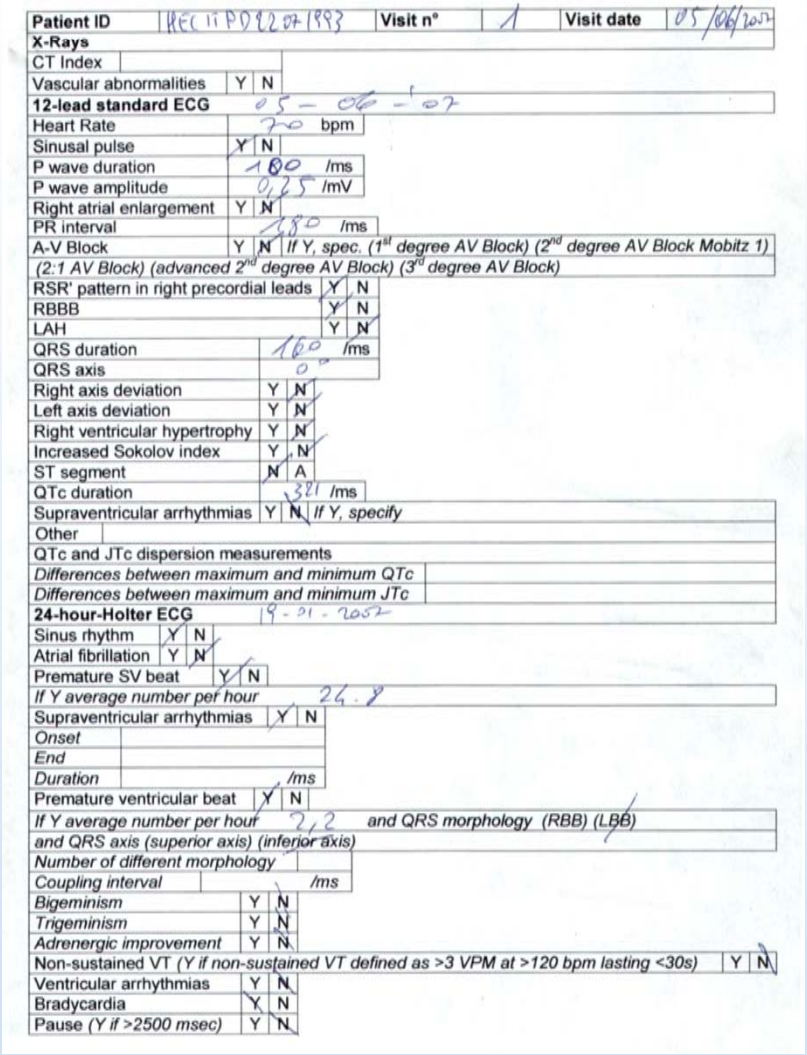
Genetic investigations	Y	N	
Karyotyping	Y	N	
FISH	Y	N	
CGH-Array (Comparative Genomic Hybridization)	Y	N	
Specific Molecular Genetic Research	Y	N	TBX5, GATA4, NKX2,5
Others	Y	N	*If Y, comment*
Provisional Genetic Diagnosis	microdeletion 22q11		

- Karyotyping: normal
- No mutations in TBX5, NKX2.5, GATA4
- CGH-Array: microdeletion 22q 1 1



ECG

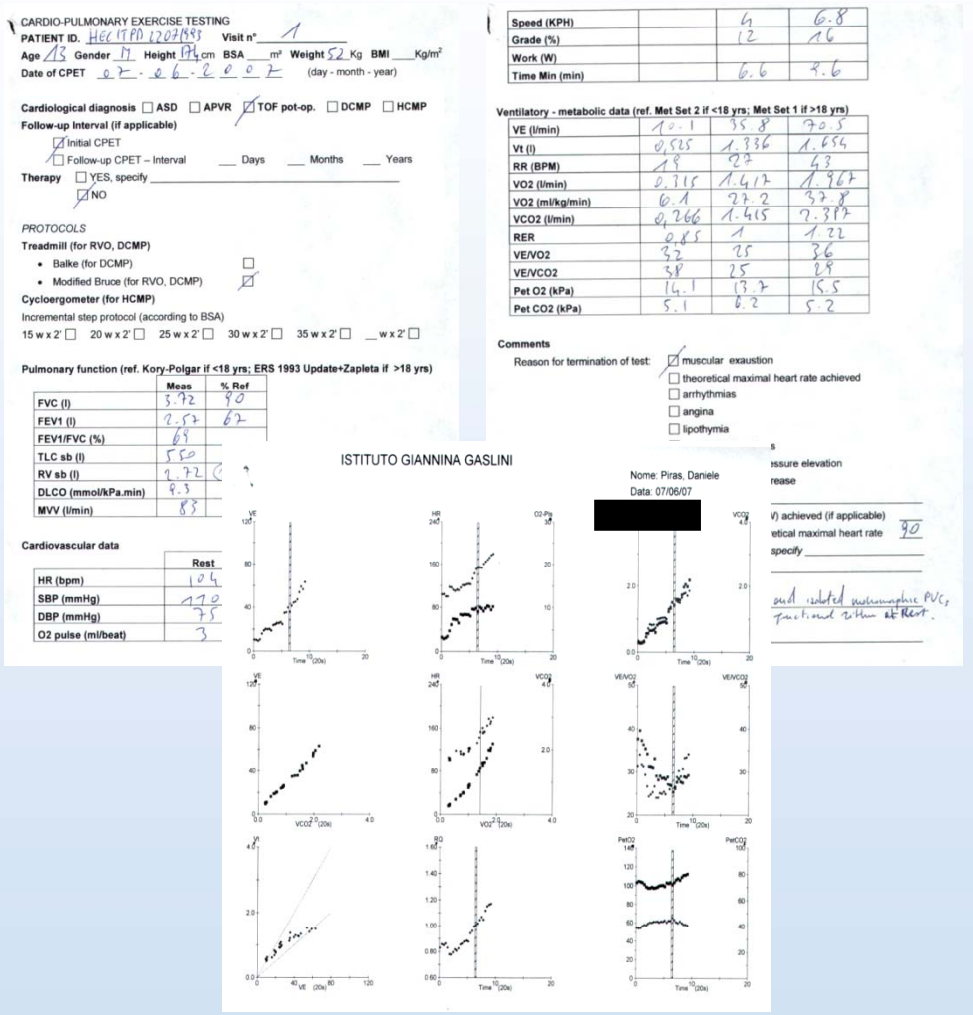
- 12 Lead ECG
  - Sinus rhythm/70 bpm;
  - P-R = 0,18 sec.;
  - RBBB (QRS= 160 msec)
- Holter Monitoring
  - Incostant I° A-V block,
  - Fairly frequent PSVBs with sporadic periods of bigeminism
  - Rare, single, PVBs (LBBB)



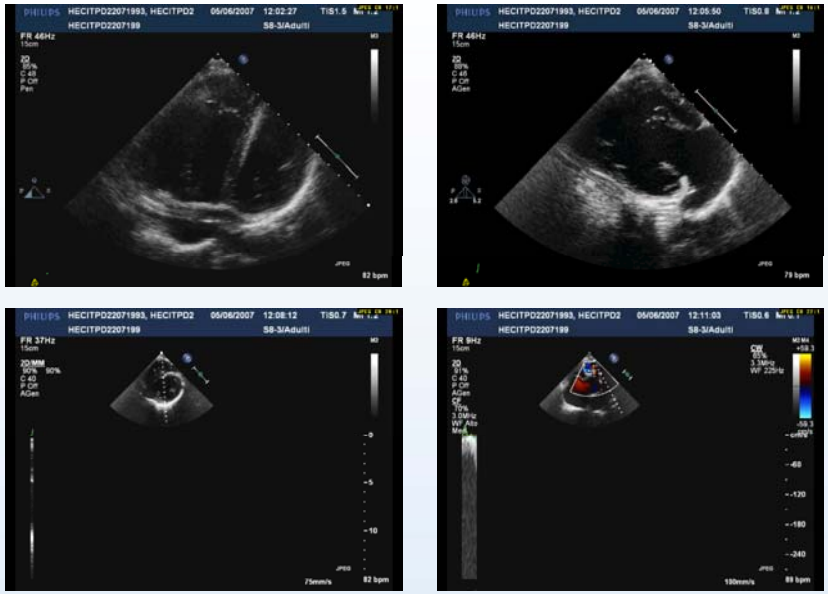
Patient ID	IREC11PD02071993		**Visit n°**	1	**Visit date** 05/06/2007
X-Rays					
CT Index					
Vascular abnormalities	Y N				
12-lead standard ECG	05 – 06 – 07				
Heart Rate	70 bpm				
Sinusal pulse	Y N				
P wave duration	100 /ms				
P wave amplitude	0,25 /mV				
Right atrial enlargement	Y N				
PR interval	180 /ms				
A-V Block	Y N	*If Y, spec. (1st degree AV Block) (2nd degree AV Block Mobitz 1) (2:1 AV Block) (advanced 2nd degree AV Block) (3rd degree AV Block)*			
RSR' pattern in right precordial leads	Y N				
RBBB	Y N				
LAH	Y N				
QRS duration	160 /ms				
QRS axis	0°				
Right axis deviation	Y N				
Left axis deviation	Y N				
Right ventricular hypertrophy	Y N				
Increased Sokolov index	Y N				
ST segment	N A				
QTc duration	321 /ms				
Supraventricular arrhythmias	Y N	*If Y, specify*			
Other					
QTc and JTc dispersion measurements					
Differences between maximum and minimum QTc					
Differences between maximum and minimum JTc					
24-hour-Holter ECG	19 – 21 – 2052				
Sinus rhythm	Y N				
Atrial fibrillation	Y N				
Premature SV beat	Y N				
If Y average number per hour	24.8				
Supraventricular arrhythmias	Y N				
Onset					
End					
Duration	/ms				
Premature ventricular beat	Y N				
If Y average number per hour	2,2	*and QRS morphology (RBB) (LBB) and QRS axis (superior axis) (inferior axis)*			
Number of different morphology					
Coupling interval	/ms				
Bigeminism	Y N				
Trigeminism	Y N				
Adrenergic improvement	Y N				
Non-sustained VT *(Y if non-sustained VT defined as >3 VPM at >120 bpm lasting <30s)*	Y N				
Ventricular arrhythmias	Y N				
Bradycardia	Y N				
Pause *(Y if >2500 msec)*	Y N				

Cardio-pulmonary Exercise Test

- Reason for terminating test: muscular exhaustion
- End step: V°
- Maximal HR: 187 bpm (90% of theoretical max HR)
- RER (peak): 1.22
- Normal BP response
- Symptoms: none
- Ecg modifications: none
- Arrhythmias: sporadic, single PSVBs and isolated monomorphic PVCs
- Preserved functional capacity (VO2 max 37.8 ml/kg/min.)



Echocardiography



- Severe RV dilation and overload
- No evidence of residual VSD
- No significant residual obstruction
- Severe pulmonary regurgitation
- Preserved bi-ventricular function

ECHOCARDIOGRAPHY

PATIENT ID. HECITPD22071993 Visit n° 1

1. **Date of Echocardiogram** 05-06-2002 (day – month - year)
2. **Follow-up Interval (if applicable)**
   - [x] Initial Echo
   - [ ] Follow-up Echo – Interval ___ Days ___ Months ___ Years
3. **Quantitative Variables**

Peak TPV (or RVOT) Velocity (CW)	2.75 m/sec	☐ Unable to assess
Mean TPV (or RVOT) Gradient (CW)	12.___ mmHg	☐ Unable to assess
Peak TR Jet Velocity (CW)	___.___ m/sec	☒ Unable to assess
Pulmonary Regurgitation Duration	320 msec	☐ Unable to assess
Diastolic Duration	470 msec	☐ Unable to assess
Pressure half-time of PR signal	___75 msec	☐ Unable to assess
Heart Rate	___82 bpm	☐ Unable to assess
Left Ventricular Internal Diameter (Dias)	5.0 cm	☐ Unable to assess
Left Ventricular Internal Diameter (Sys)	2.7 cm	☐ Unable to assess
Right Ventricular Internal Diameter (Dias)	6.6 cm	☐ Unable to assess
Blood Pressure (Sys)	125 mmHg	☐ Unable to assess

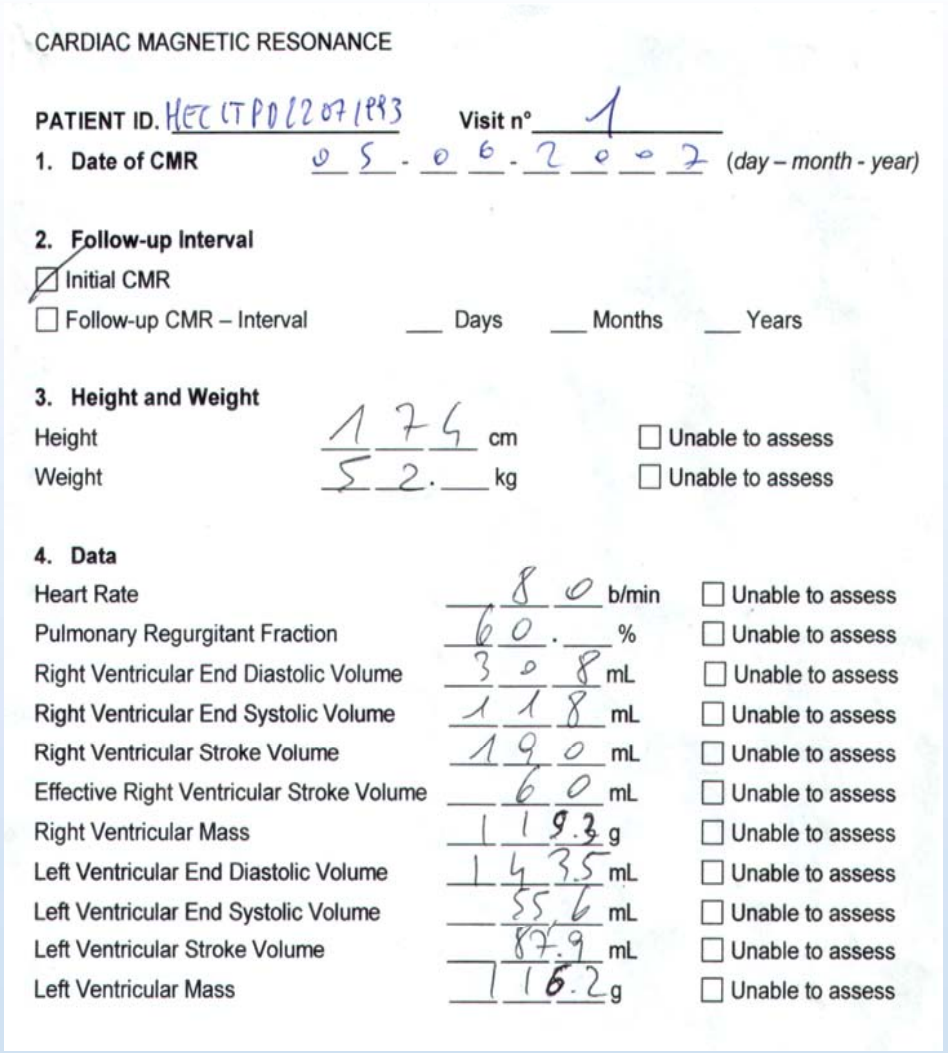
4. **TPV (or RVOT) Regurgitation**
   - [ ] None [ ] Moderate [ ] Unable to assess
   - [ ] Trace [x] Severe
   - [ ] Mild
5. **Tricuspid Regurgitation**
   - [x] None [ ] Moderate [ ] Unable to assess
   - [ ] Mild [ ] Severe
6. **RV Dilation**
   - [ ] None [ ] Moderate [ ] Unable to assess
   - [ ] Mild [x] Severe
7. **Reduction in RV Function**
   - [x] None [ ] Moderate [ ] Unable to assess
   - [ ] Mild [ ] Severe
8. **Is there paradoxical septal motion?**
   - [ ] No [x] Yes [ ] Unable to assess

9 Restrictive physiology -> no

10 LV EF 57%

Cardiac Magnetic Resonance

- Severe RV dilation (EDV z-value + 7)
- Good RV function (EF 62%)
- Dilated pulmonary infundibulum without evident diskynesia
- Severe pulmonary regurgitation (RF ~ 60%)
- Normal LV volumes and function



CARDIAC MAGNETIC RESONANCE

PATIENT ID. HECITP0220719893 Visit n° 1

1. Date of CMR 05-06-2007 (day – month - year)

2. Follow-up Interval
- [x] Initial CMR
- [ ] Follow-up CMR – Interval ___ Days ___ Months ___ Years

3. Height and Weight

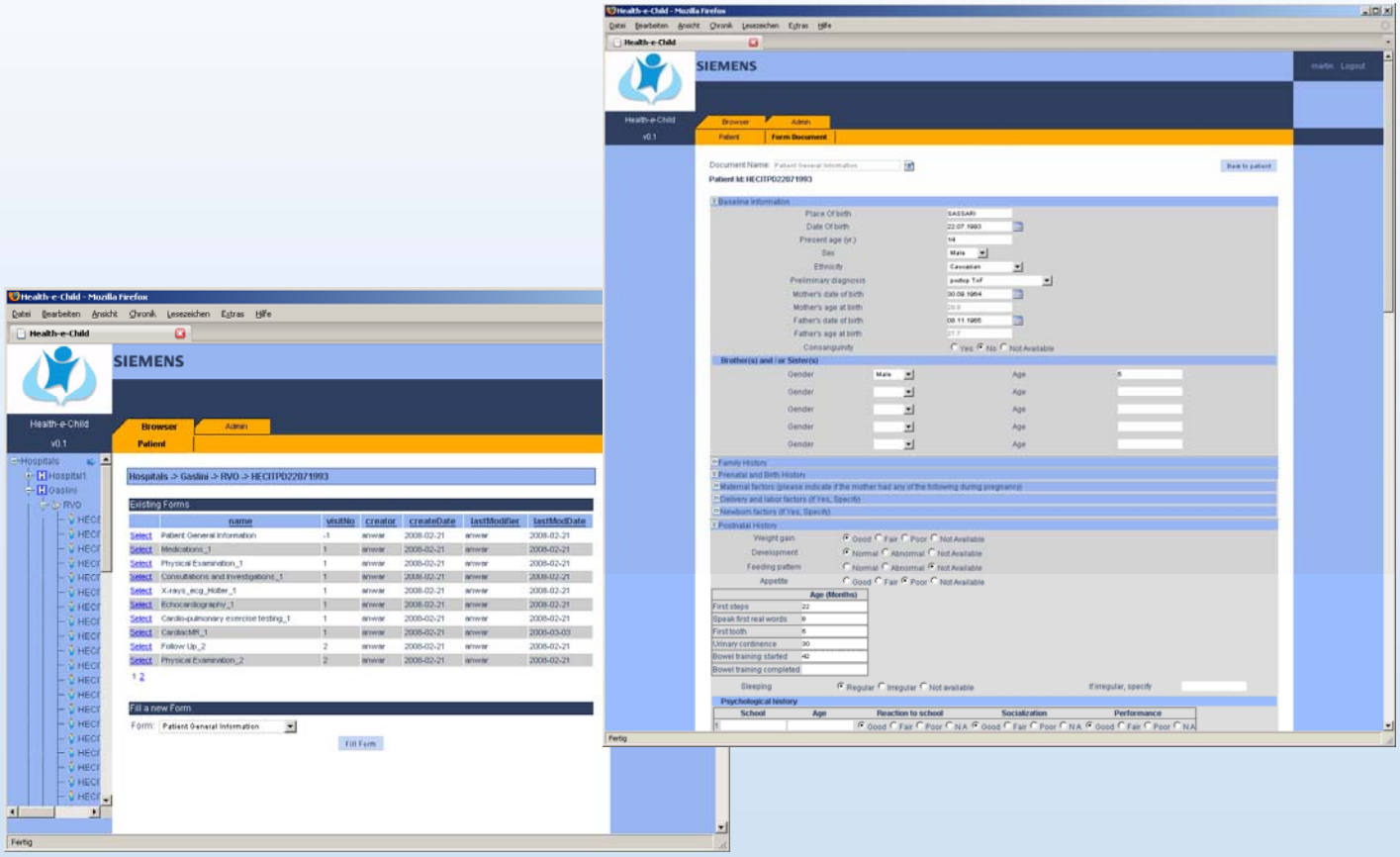
Height	174 cm	☐ Unable to assess
Weight	52.___ kg	☐ Unable to assess

4. Data

Heart Rate	80 b/min	☐ Unable to assess
Pulmonary Regurgitant Fraction	60.___ %	☐ Unable to assess
Right Ventricular End Diastolic Volume	308 mL	☐ Unable to assess
Right Ventricular End Systolic Volume	118 mL	☐ Unable to assess
Right Ventricular Stroke Volume	190 mL	☐ Unable to assess
Effective Right Ventricular Stroke Volume	60 mL	☐ Unable to assess
Right Ventricular Mass	119.3 g	☐ Unable to assess
Left Ventricular End Diastolic Volume	143.5 mL	☐ Unable to assess
Left Ventricular End Systolic Volume	55.6 mL	☐ Unable to assess
Left Ventricular Stroke Volume	87.9 mL	☐ Unable to assess
Left Ventricular Mass	116.2 g	☐ Unable to assess

De-Identified Electronic Patient Record

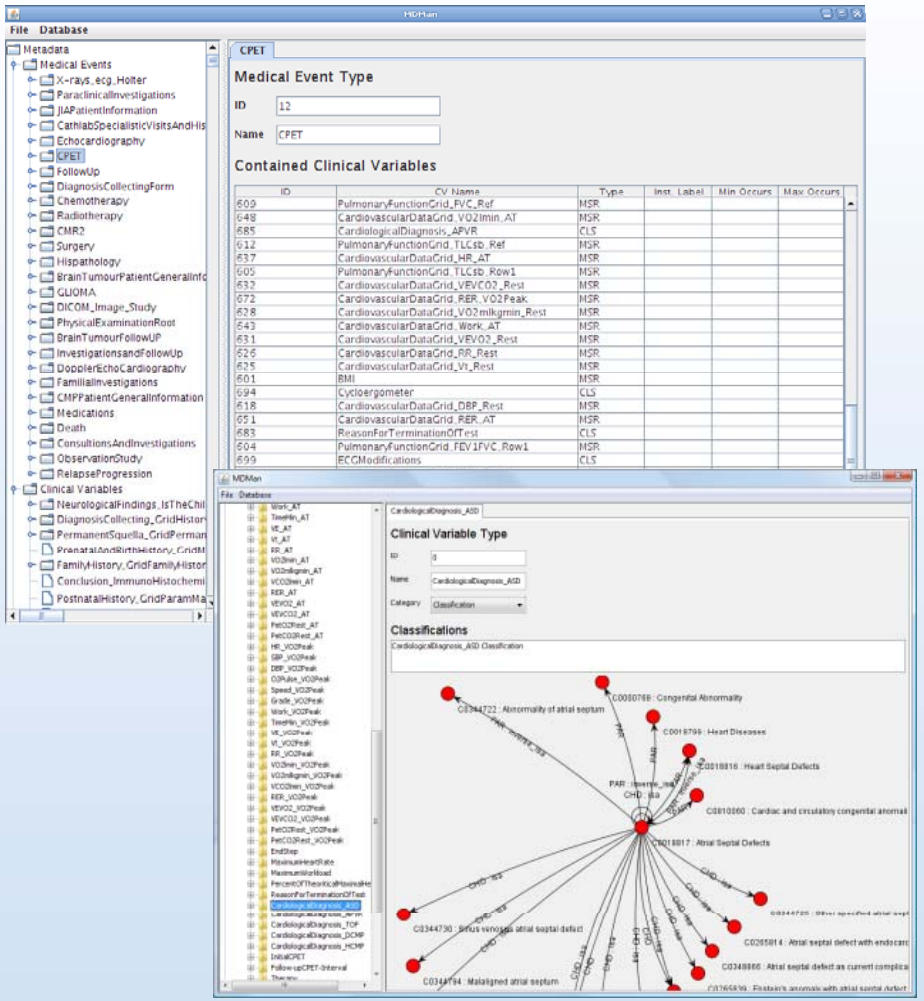
- Siemens web based data collection tool
- Adjusted for Health-e-Child



Data Import into HeC

- Migration tool imports XML forms created by Siemens data collection tool
- Tool semi-automatically analyses forms and suggests name and type according to HeC meta data model
- Tool instantiates HeC data model and migrates patient data using gateway API
  - no need to know underlying data base management system

➢ **After once establishing the mapping, patient data can be migrated to the HeC grid fully automatically**



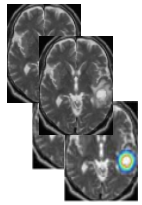
Case Database, Patient Browser & P2P3

Data Overview

- Multi-level Integrated Data Model (IDM)
  - From Organs, to Cells, to Genes…
  - Medical Images along with clinical records
- Multi-centre Case Database (ICD)
  - ICDs are federated and seen as a single one

- Database Backend Abstraction (AMGA Layer)
- Transactional insertion and updates
- Replication of portions of the data
- Data/User/Group access rights synchronised with VO (Cron Job)

- Patient privacy is ensured from the beginning
  - Anonymisation client-side
  - UUIDs for all patient folders
- Peer-To-Peer Patient Privacy for storing mappings (Patient Sheet)
  - Useful for retrieving concerned sets of patients



Security & Connectivity Overview

-2FA, so-called “Strong” Authentication
  - -Improved GSI Model (VOMS-enabled proxy server-side)
  - -X509 Certificate on the Key (making it mobile)
- -Single Signon

- -Additional Security Factors
  - -PIN Code
  - -Magic Number
  - -OTP for all Gateway invokations
  - -Heartbeat mechanism for renewing resources lifetimes

- -Portable Solution, cross OS (no installation on client)
  - -Standard USB port/stick
- -Simplified Integration for Grid-agnostic applications
- -Most advanced AJAX library for interacting with GRID

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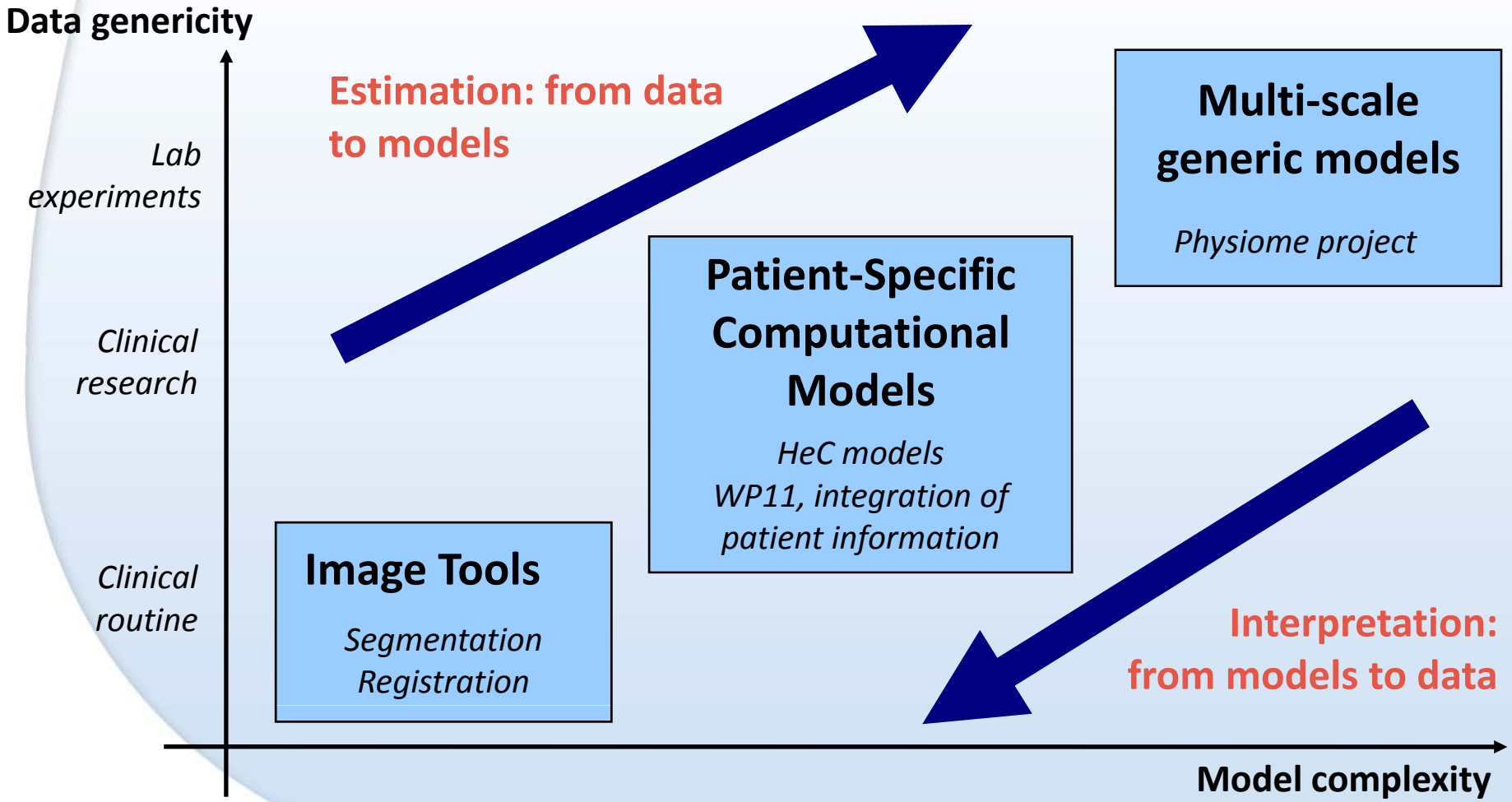
  - Data Acquisition
  - ➢ *Imaging and Simulation*
  - Knowledge Discovery and Decision Support

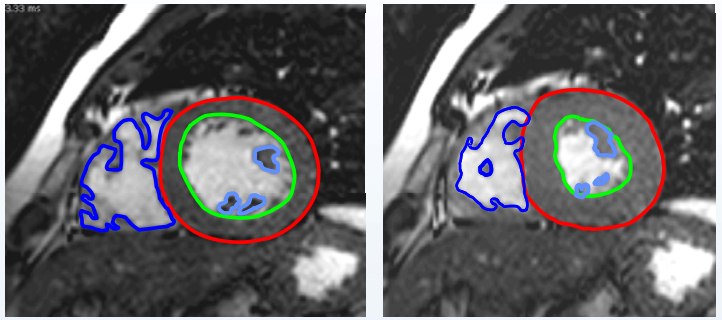
Links between Models and Clinical Data



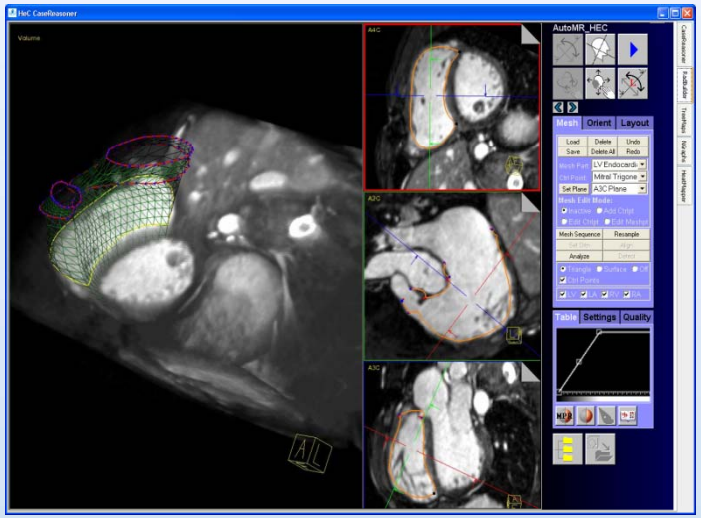
Step 1: Anatomical Model from Cardiac MR

- Anatomical model of right ventricle (RV) created from HeC data (based on 30 isotropic volumes from Gosh)
- Semi-automatic initialisation of model based on detection library from Siemens Corporate Research
- Multi-sequence view for model editing

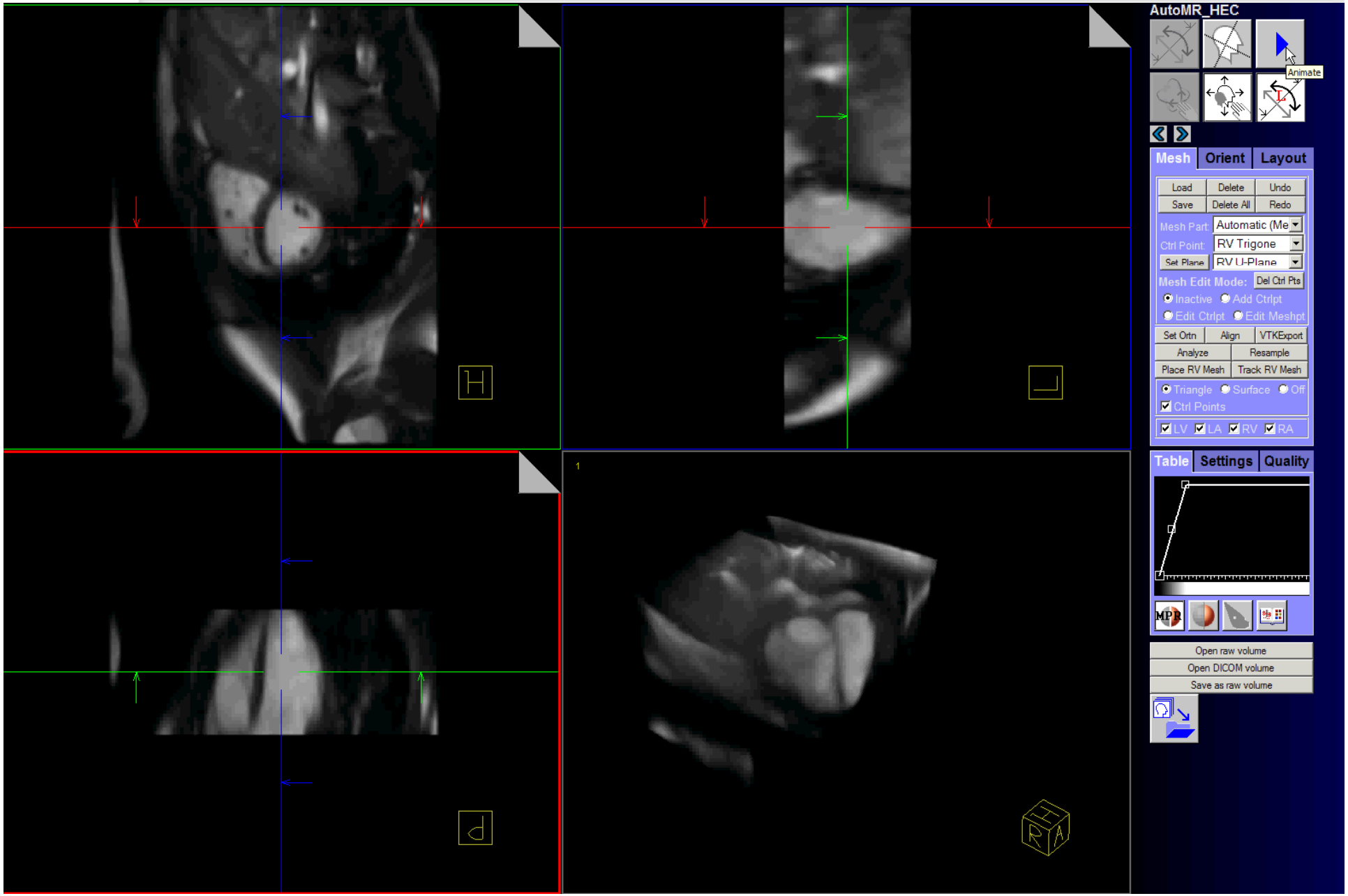
➔ Fast, accurate 4D quantification of RV volumes (ES, ED) from which RV ejection fraction and further measurements can be easily derived



Manual annotations in diastole and sysole



HeC application for semi-automatic annotations


AutoMR_HEC
Animate
Mesh
Orient
Layout
Load
Delete
Undo
Save
Delete All
Redo
Mesh Part:
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Ctrl Point:
RV Trigone
Set Plane
RV U-Plane
Mesh Edit Mode:
Del Ctrl Pts
Inactive
Add Ctrlpt
Edit Ctrlpt
Edit Meshpt
Set Ortn
Align
VTKExport
Analyze
Resample
Place RV Mesh
Track RV Mesh
Triangle
Surface
Off
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LV
LA
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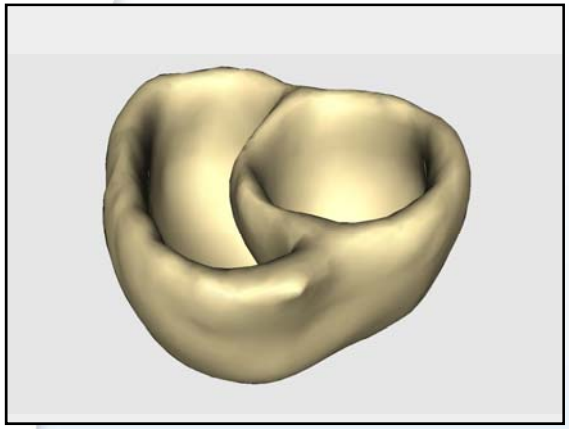
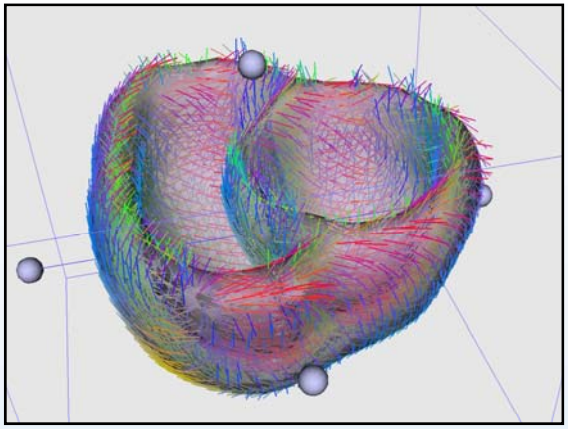
Table
Settings
Quality
MPR
Open raw volume
Open DICOM volume
Save as raw volume

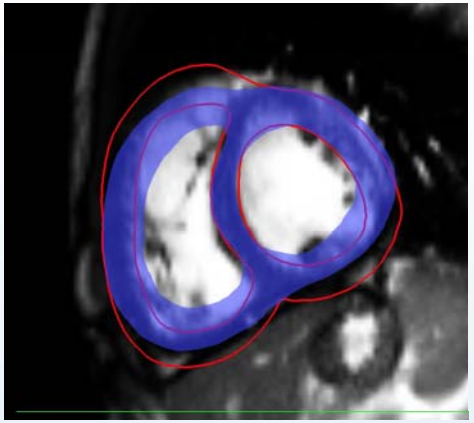
Step2: Electromechanical Model and Simulation



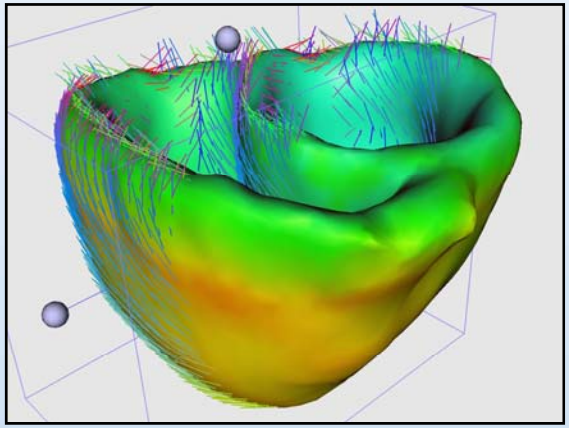
Volumetric mesh at time 0



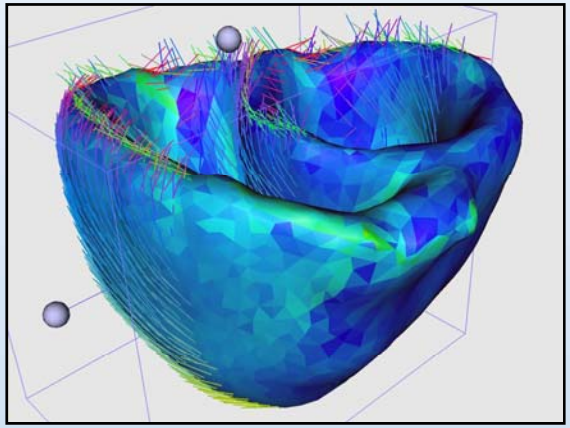
Simulated fibres (+60° on the endocardium to -60° on the epicardium)



Visual adjustment of simulation (Segmentation / Simulation)



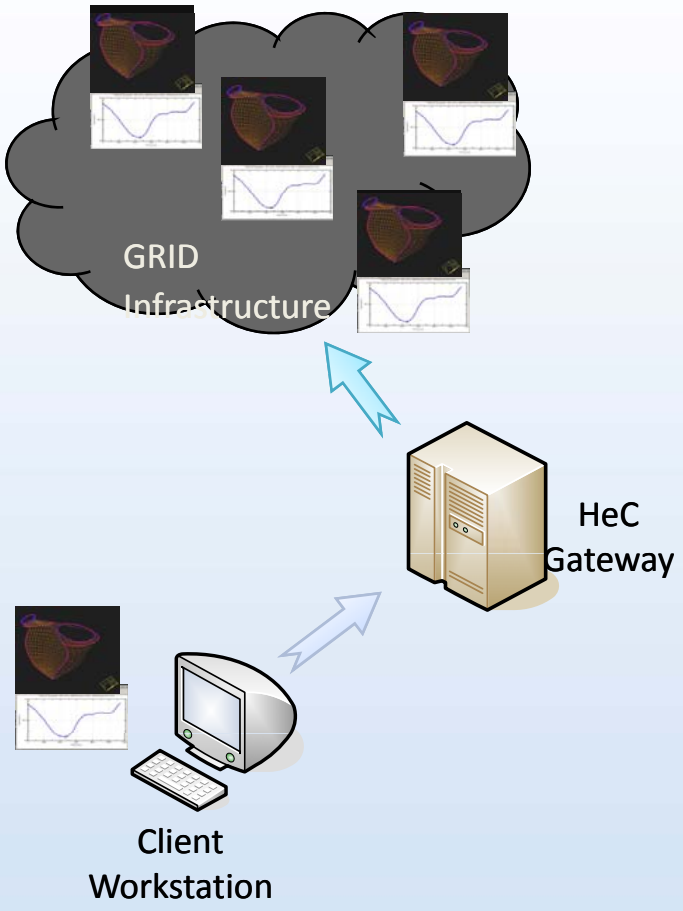
Simulated beating heart + fibres Colors: contraction



Simulated beating heart + fibres Colors: strain anisotropy

Status of Imaging/Modelling wrt Grid

- DICOM images and anatomical meshes can be stored and retrieved from the grid
- Similar meshes can be searched (distributed algorithm: similarity rankings are calculated locally and merged by calling node)
- Electromechanical model personalisation is done manually by expert → only prerecorded videos are shared
- Next step: sharing of precomputed electromechanical models (requires dedicated viewer from INRIA)



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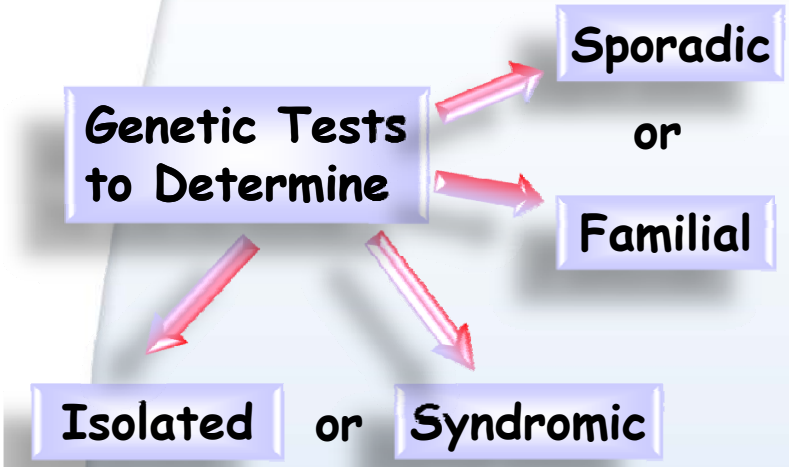
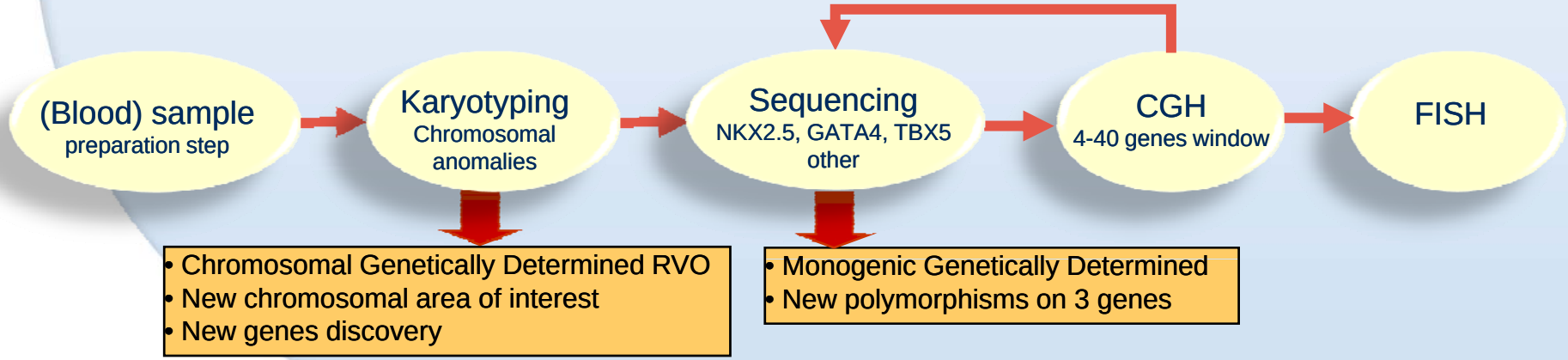
Research Goal 1: Identification of Associated Gene Anomalies



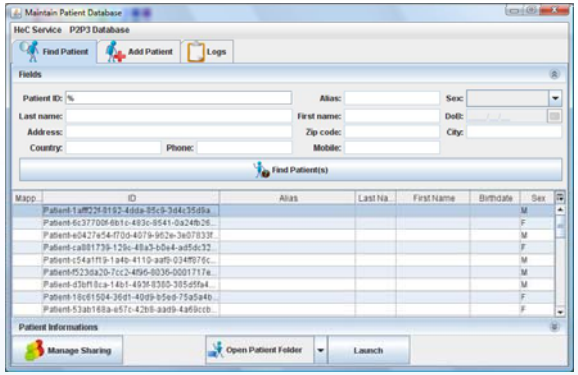
If a causative gene anomaly is known, genetic counseling can be more accurate:

- detection of mutation in all family members
- more precise prediction of risk
- preconceptional molecular diagnosis (family planning)
- prenatal diagnosis if necessary



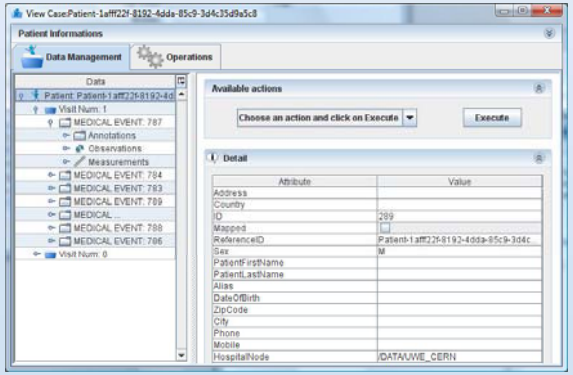
HeC Toolbar

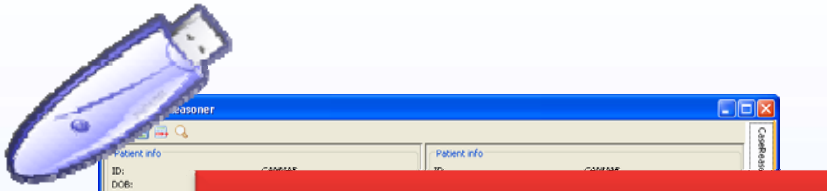
1. The clinician browses the current patient in Health-e-Child

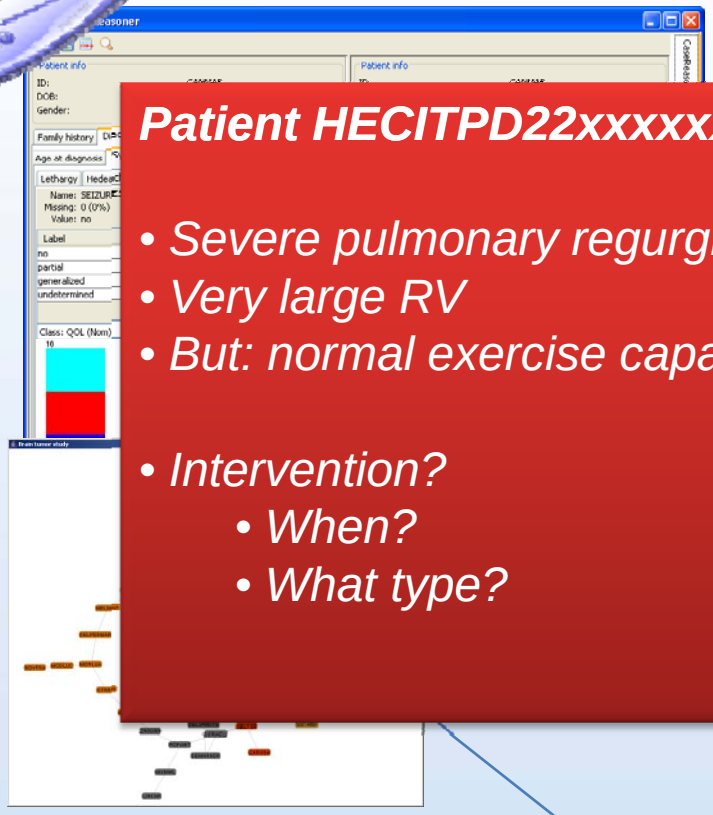


2. A (web) browser is used to find relevant information associating microdeletion 22q11 with ToF
3. She marks relevant resources
4. The resource (and meta-information) gets recorded

5. The resource is associated with the patient record
6. Such external resource can be accessed for similar patients







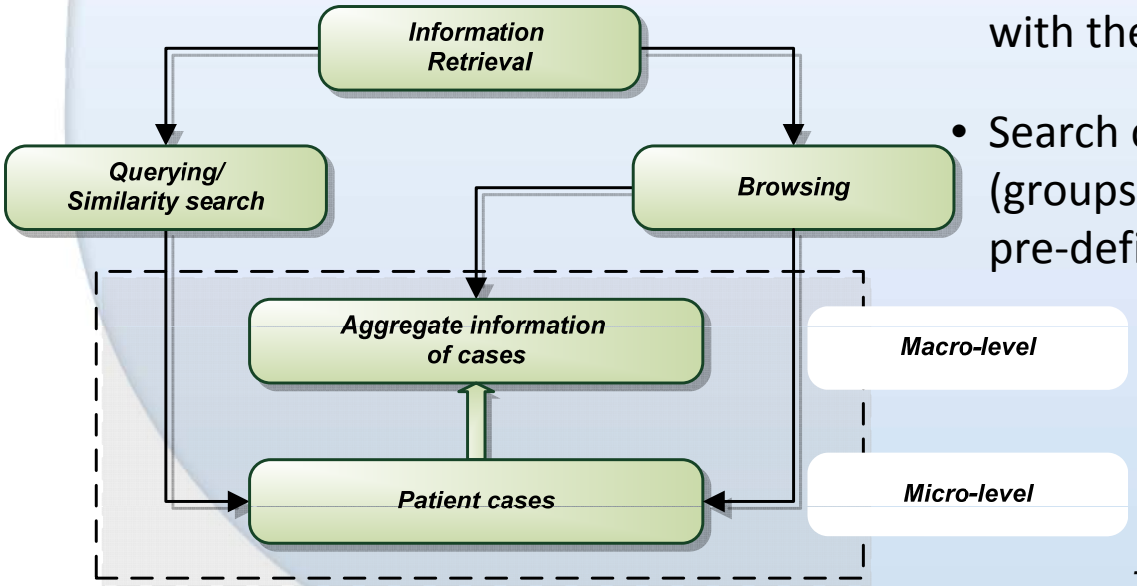
***Patient HECITPD22xxxxxx** revisited*

- *Severe pulmonary regurgitation fraction*
- *Very large RV*
- *But: normal exercise capacity, no symptoms*

- *Intervention?*
  - *When?*
  - *What type?*

HeC CaseReasoner

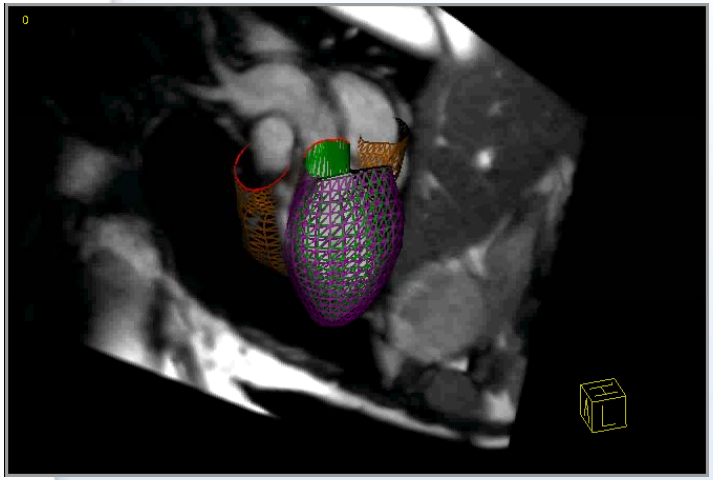
- HeC platform enables access to potentially unlimited number of cases
- HeC CaseReasoner leverages the grid-based HeC platform
  - Reviewing similar cases can guide clinicians to best decision
    - Functionality: case retrieval/similarity search, filtering, visualization
  - Statistical analysis of similar patients can lead to new clinical hypothesises
    - E.g., 10 patients with severely dilated RV and normal exercise test are compared with the general cohort
    - Search context is defined as a subset of (groups of) features of interest from the pre-defined feature hierarchy

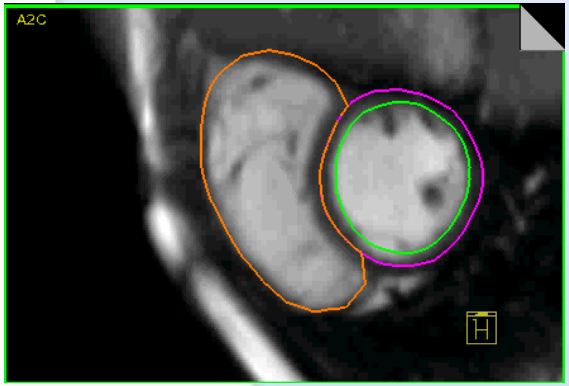


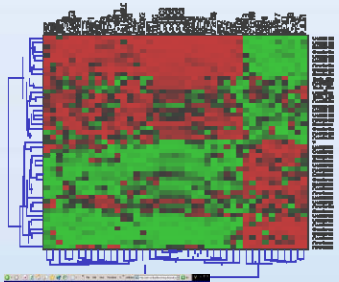
The information retrieval process
(adapted from [Zhang. Visualization for Information Retrieval, Springer, 2007])

Platform at Work

Current Patient Data







Hospital 1 *Hospital 2* ... *Hospital N*

"Do I Operate"

Search

Knowledge Base

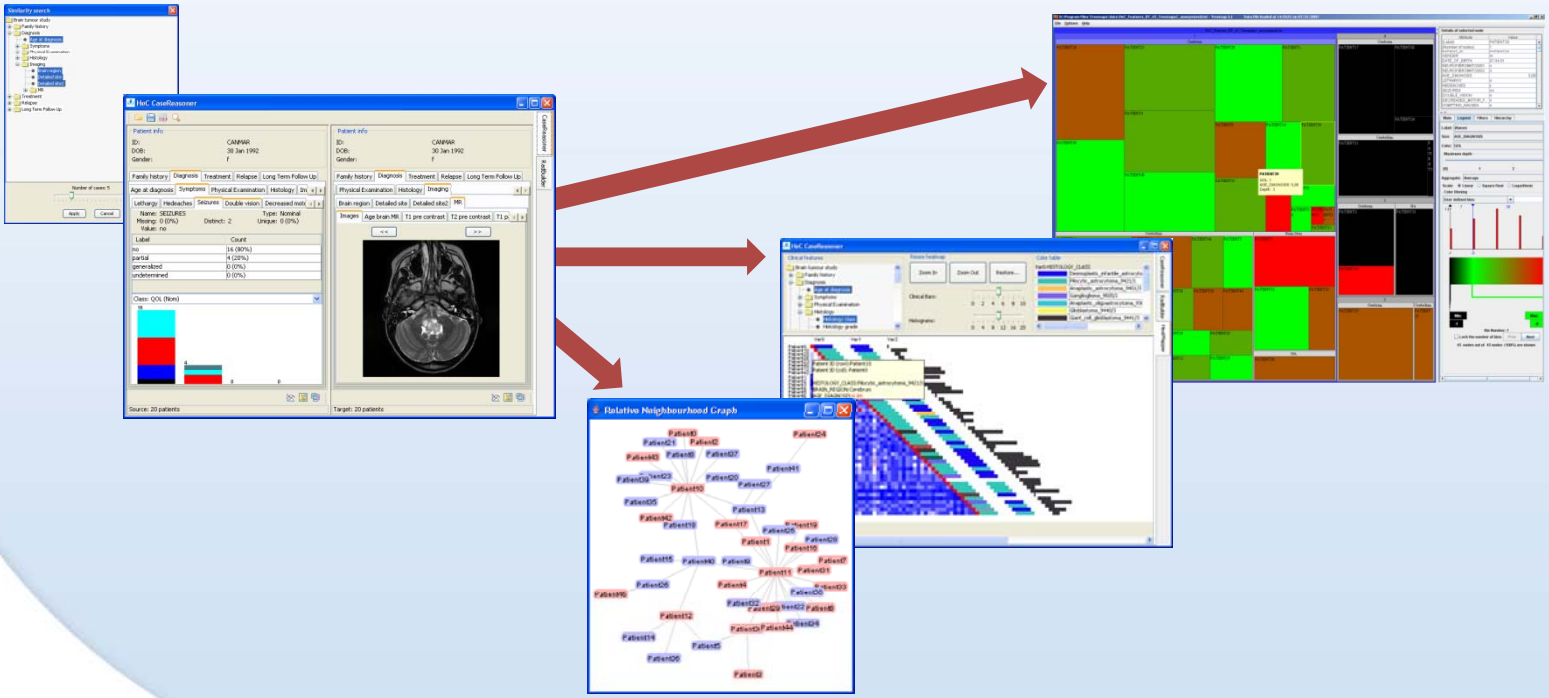
Unhealthy *Healthy*

Action

Unhealthy *Healthy*

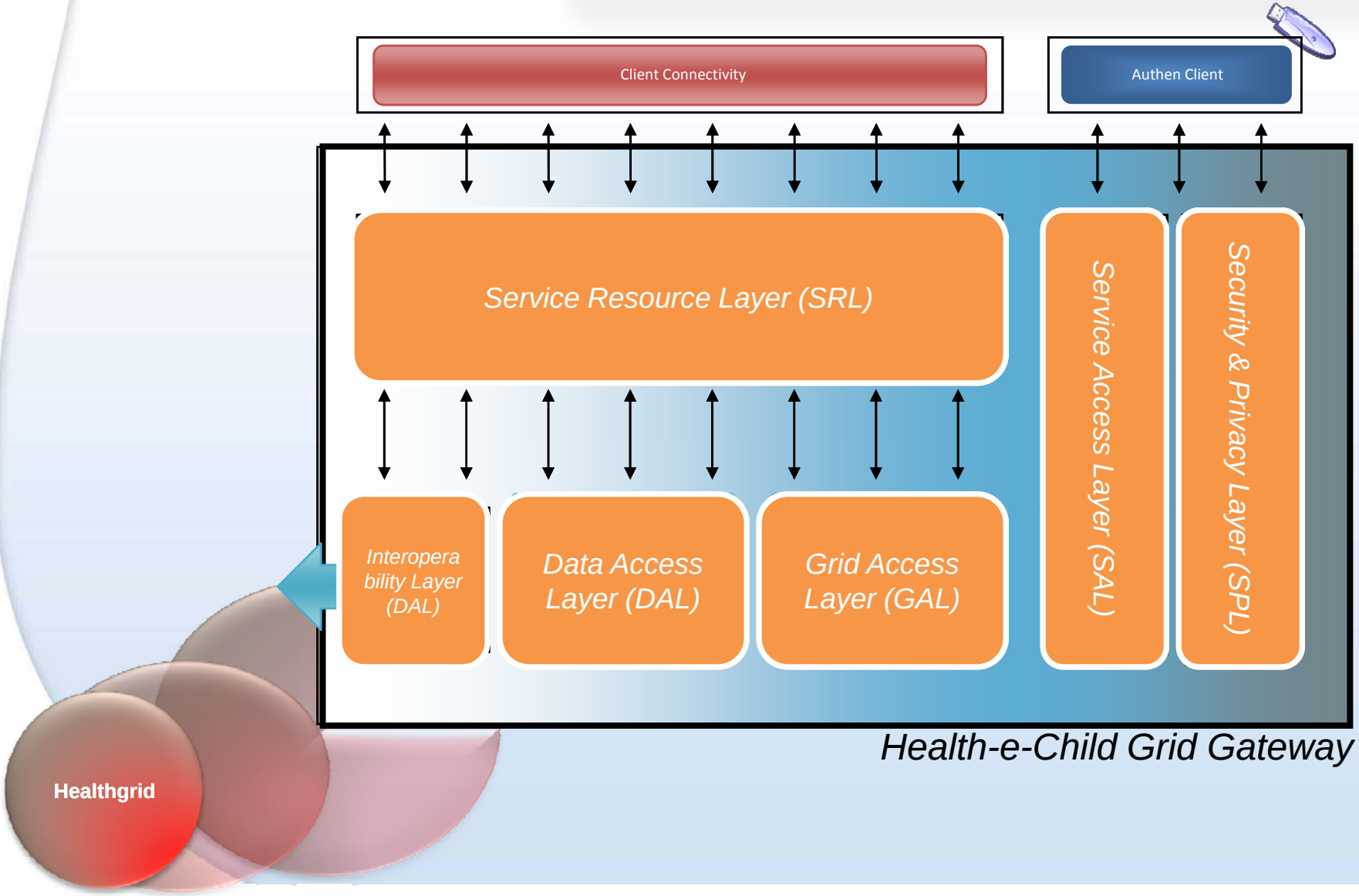
Visualization of Result Set

- 3 specific non-traditional visualisation techniques
  - Treemaps [Shneiderman, 1992] (integration in progress)
  - Neighbourhood graphs [Toussaint, 1980]
  - Combined correlation plots/heatmaps [Verhaak, 2006]



Thank you for your attention!

Service-Oriented Architecture





Service-Oriented Architecture

Applications Overview

-Gateway is a Service-Oriented Architecture (SOA)
- -Allows Services Publications, Discovery and Composition
  - -From simple stateless to more complex stateful ones

-Services Composition is handled by a Workflow Management System
- -Extended ActiveBPEL
- -Generic Stub mechanism
- -Possibility to deploy processes as services or run on-the-fly

-Replicated Gateway Information System (ISD)
- - Fine-grained control over functionality and IS data
  (Same approach as ICD)