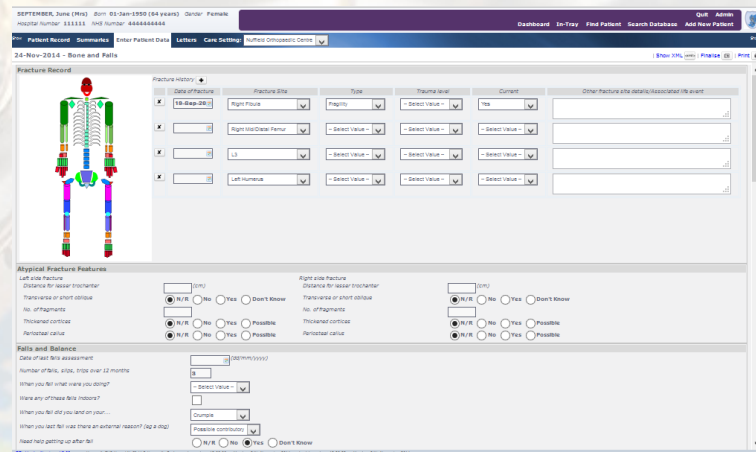




cityEHR – Electronic Health Records Using Open Health Informatics



Mayo Clinic, 1907



Oxford University Hospital, 2014



Open Health Informatics

cityEHR is an open source health records system developed using the principles of open health informatics

Open source software

Open standards

Open system interfaces

Open development processes



CITY UNIVERSITY
LONDON

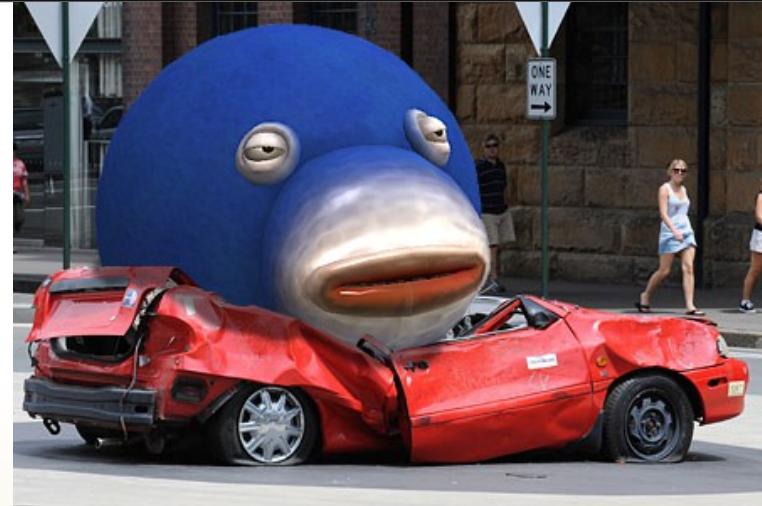
cityEHR

Open Health Informatics for Electronic Health Records

Making Top Down Work for Us

- Top down approaches can crush the life out of the grass roots
 - Not matched to requirements
 - No stakeholder buy-in
 - No innovation

- But top down can also mean giving freedom to do things locally that match exactly what is required



Using Open Standards Properly

- Open standards can mean
 - Everyone has to do everything in the same way
 - Not matched to requirements
 - No stakeholder buy-in
 - No innovation
- But open standards can also mean giving freedom to do things locally in a way which will allow data exchange and functional interoperability with others



cityEHR - Empowering The Twitter Knitter

Freedom to meet local requirements

- Allow clinicians to create their own information models

Easy to develop

- Do this using familiar tools such as spreadsheets

Enforce open standards

- Built on an architecture that uses open standards for everything

Create an enterprise system

- Press a button to deploy an enterprise scale system

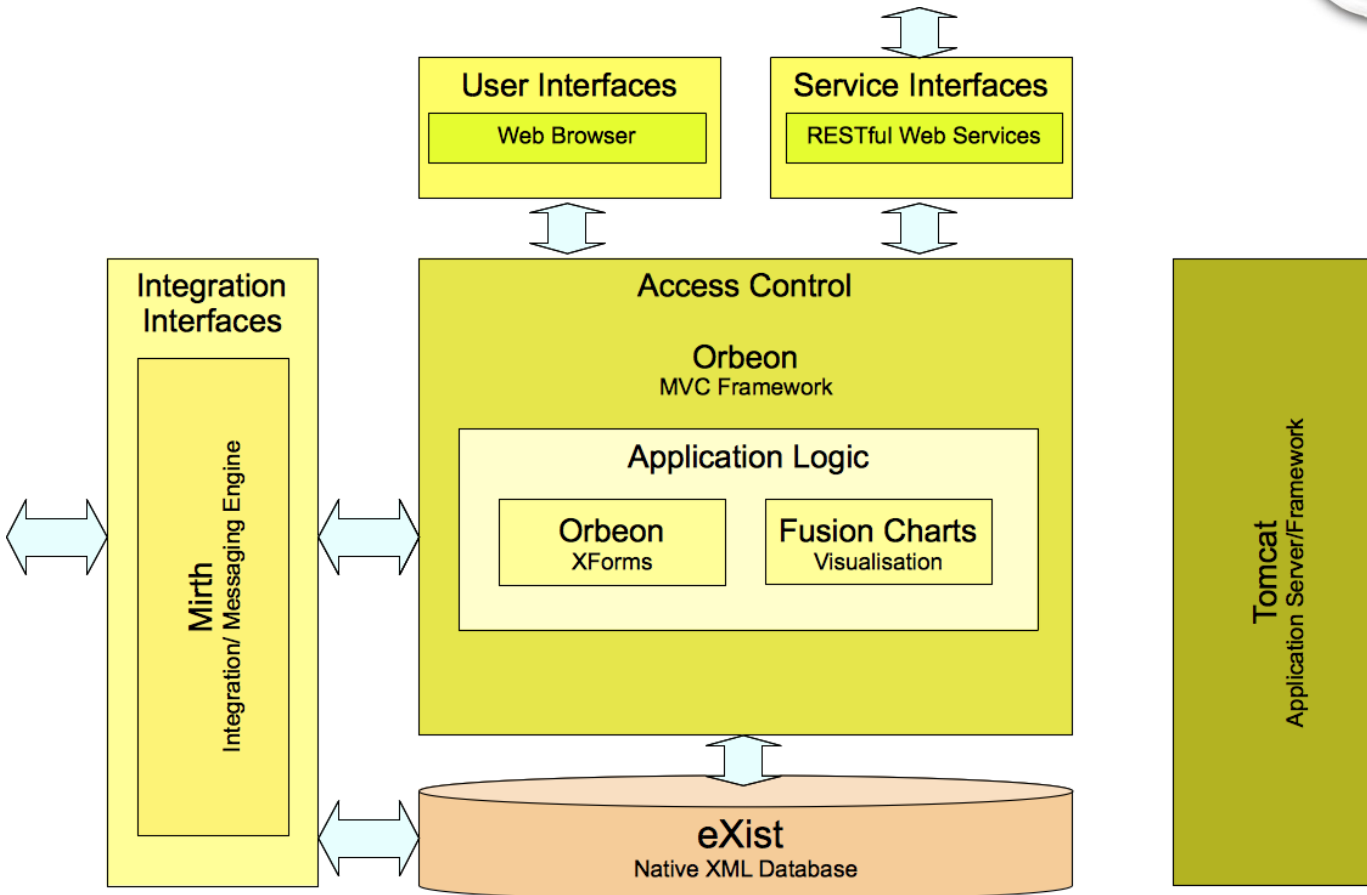


Blaine Cook
Original Lead Architect, Twitter

Doing his knitting at the XML
Summer School, Oxford, 2010

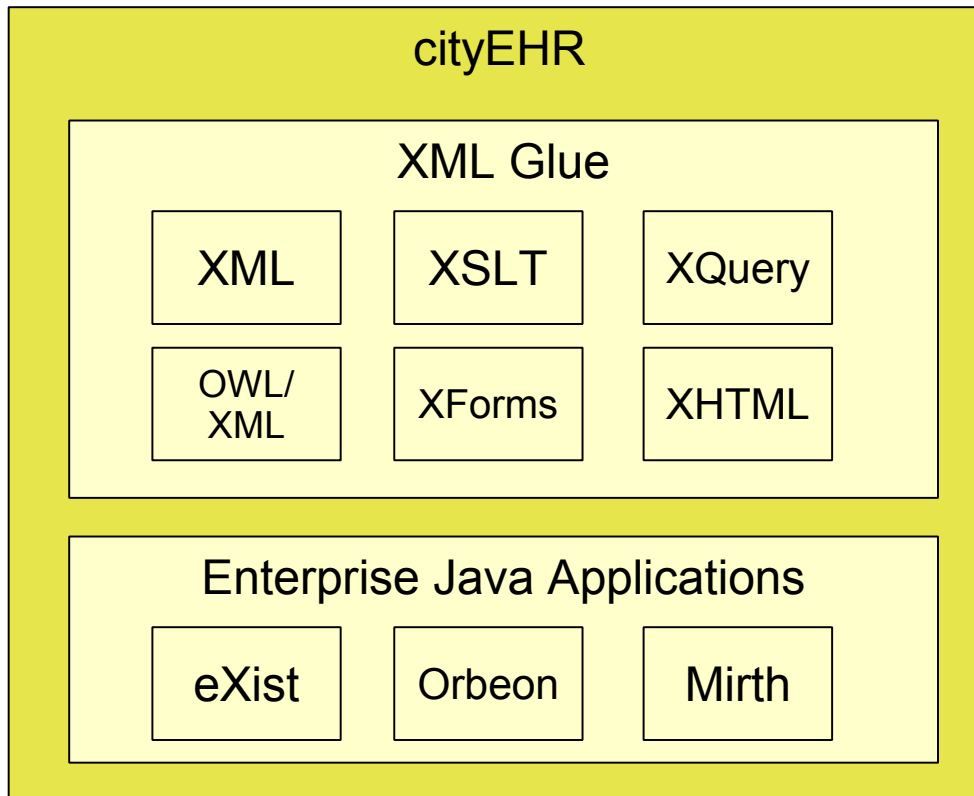
cityEHR Platform

- cityEHR is built using open source software
- An enterprise-scale health records system
- Following research at City University, London
- Distributed under the LGPL license



cityEHR is an XRX Application

- cityEHR is built using XML technology
- Built on Java components, but has no Java code of its own
- Is an XRX application – open text, no compiled code
- XForms – REST - XQuery

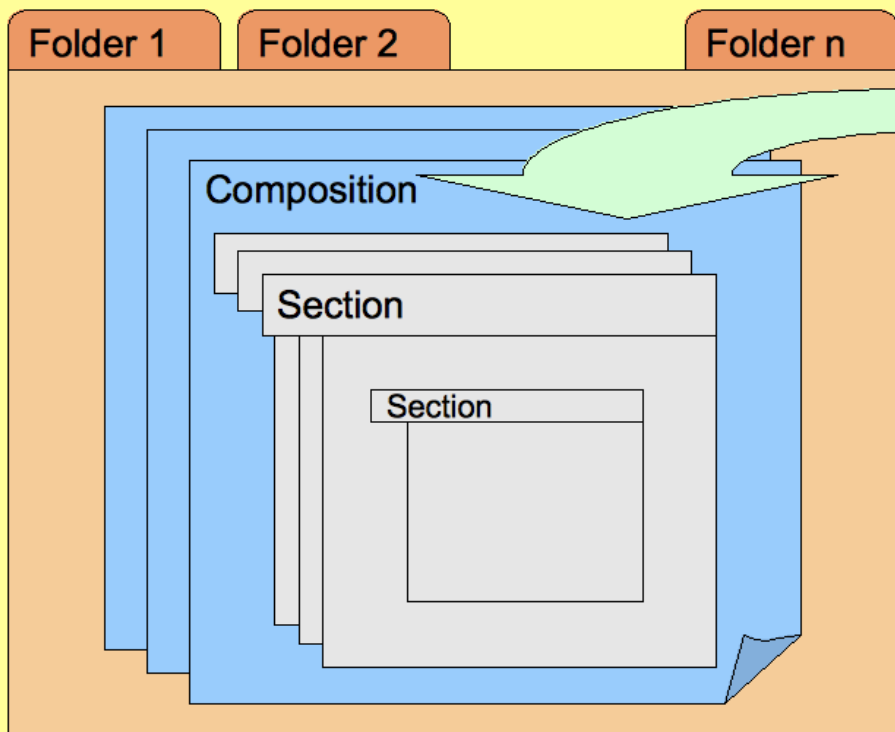




Open Standards

- cityEHR is based entirely on open standards
- Structure is based on ISO 13606
- All clinical data are stored in HL7 CDA
- All information is stored and manipulated as XML

EHR_EXTRACT



Clinical Document

Header

Body

Non-XML Body

Structured Body

Entry

Element

Cluster

Element

Cluster

Clinician-led Development

- Clinicians create clinical models for their own systems
- Using the cityEHR architectural model
- And the hierarchical ORCHID clinical classification and coding architecture
 - Used for diagnosis, drugs, test results, etc
- The runtime EHR system is generated from the information models
 - views of the patient record
 - search criteria
 - data collection forms
 - clinical messages
 - (pathways, orders, prescriptions)

Artefact

Information
Architecture

Information
Model

System
Configuration

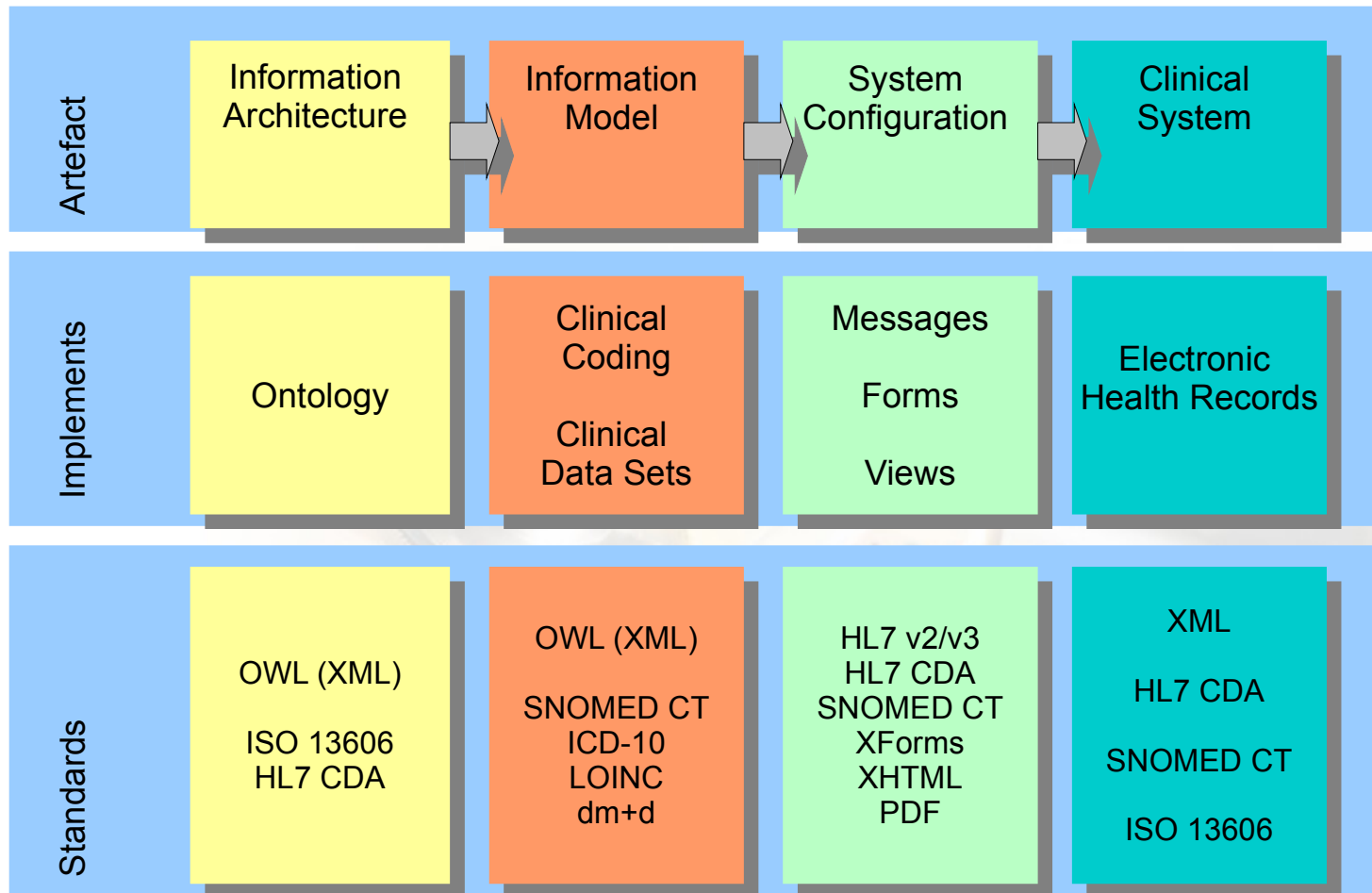
Clinical
System





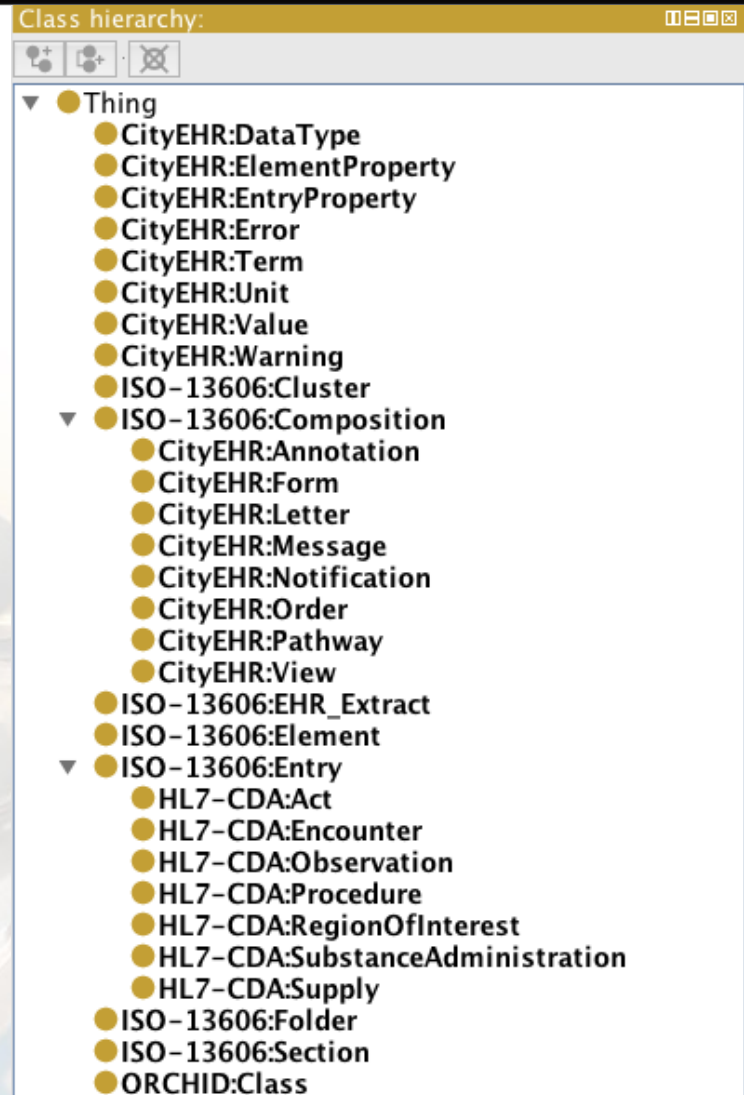
Full Modelling Process

- Standards based
- Ontology driven
- Clinician led



Ontology – Architecture and Models

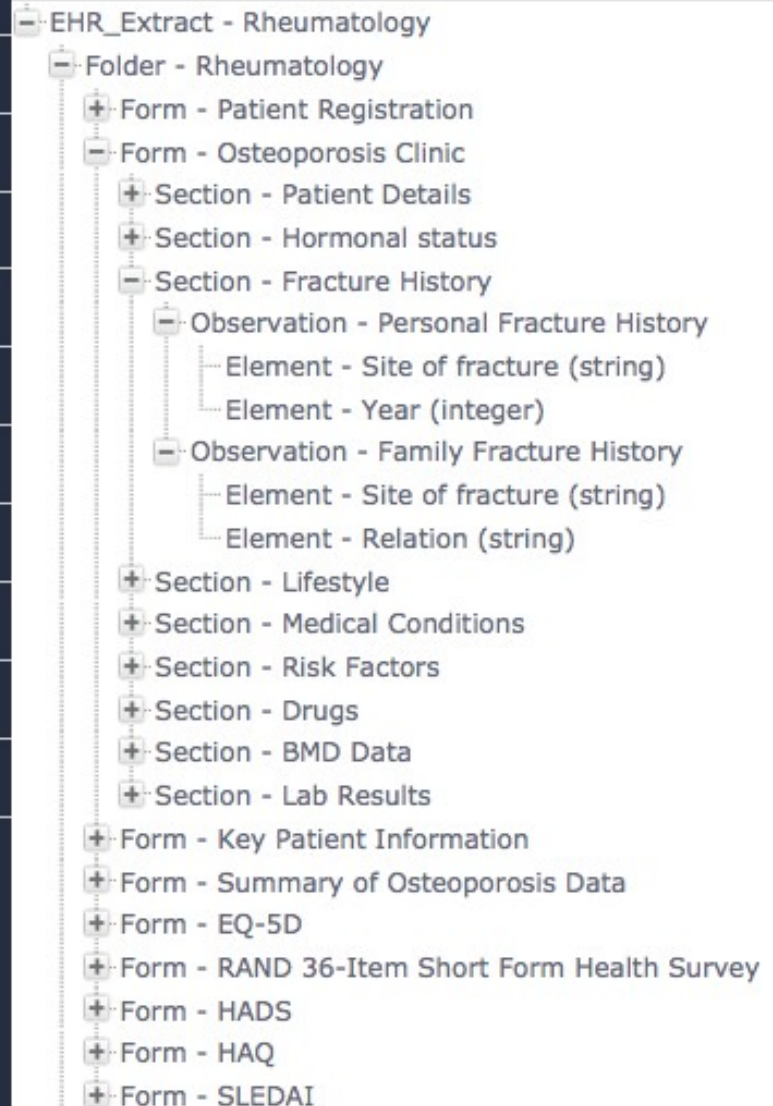
- Information model is represented as an ontology
- Model is built for a particular application/specialty
 - Corresponds to ISO-13606 EHR_Extract
- Based on the ontology architecture that uses
 - ISO-13606
 - HL7 CDA
 - cityEHR (foundation of EHR extensions)
 - ORCHID (foundation of coding extensions)
- Represented as OWL/XML
- Can be maintained using Protégé tooling





Data Dictionary

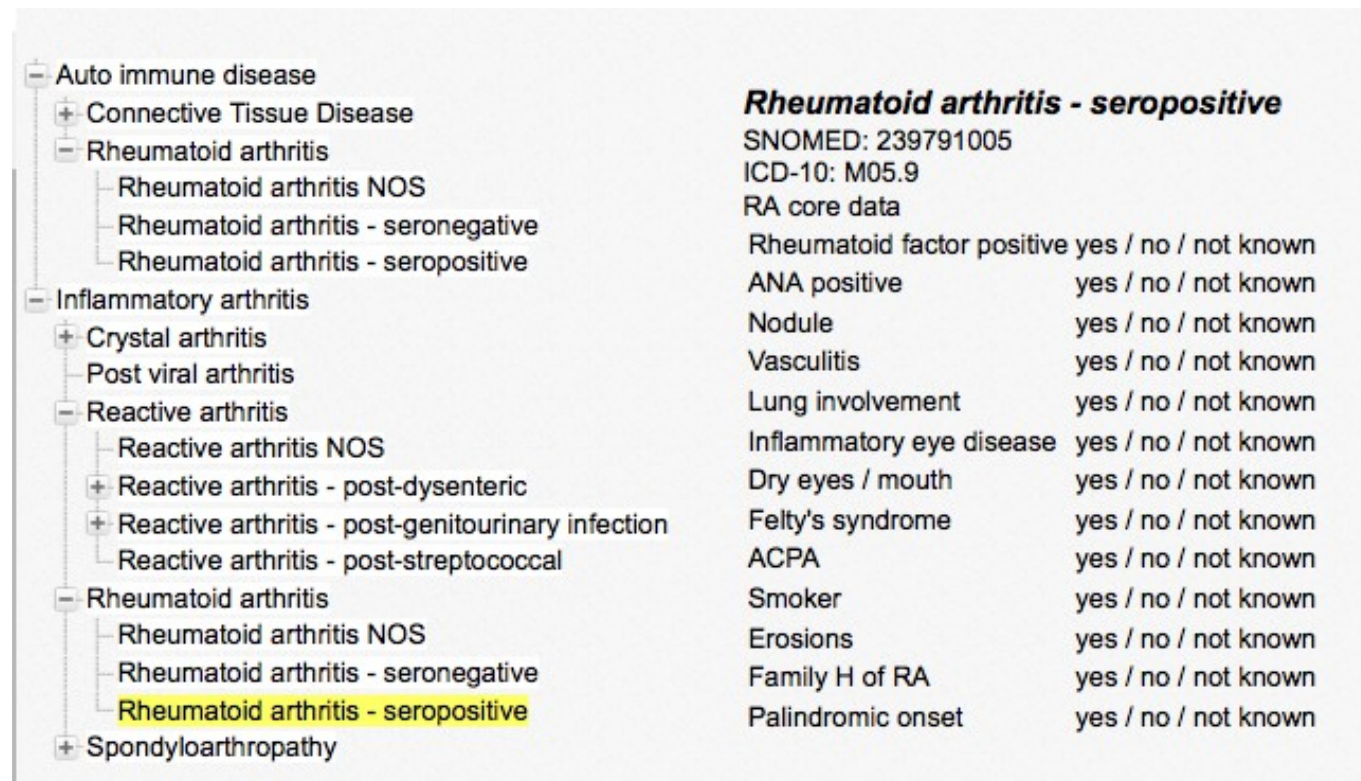
- The Data Dictionary combines ISO-13696 and HL7 CDA structures
- Elements
- Clusters of Elements
- Entries
- Arranged (reused) in
 - Sections
 - Compositions (HL7 CDA Document)
 - Messages
 - Views
 - Forms





Class Hierarchies and Clinical Coding

- Class hierarchies are Directed Acyclic Graphs
- Used for diagnosis, medications, laboratory tests, etc
- Three-level, with Core Data Sets to represent phenotypes
- Nodes can also carry clinical coding (SNOMED, ICD-10, etc)





Tooling – One Architecture, Many Tools

- Models are created using standard tools
- Spreadsheets (Open Office)
- Graphing tools (YED)
- Mind maps (Freemind)

The screenshot displays a multi-tool environment. At the top, a window titled 'Inflammatory arthritis and CTD.graphml - yEd' shows a mind map with numerous nodes and connecting lines. Below it, a window titled 'ORCHID palette - v1.1' contains a palette of icons for different data types. In the foreground, an OpenOffice Calc spreadsheet is open, displaying a table with columns for 'SectionID', 'Display Name', 'Layout', 'PreConditions', 'Conditions', 'Contents', and 'H'. The table lists various medical conditions and their associated data points, such as 'TestosteroneHistory', 'BMDData', and 'HRT History'. The spreadsheet is currently showing the 'TestosteroneHistory' section, with a filter applied to 'Boolean=true'.

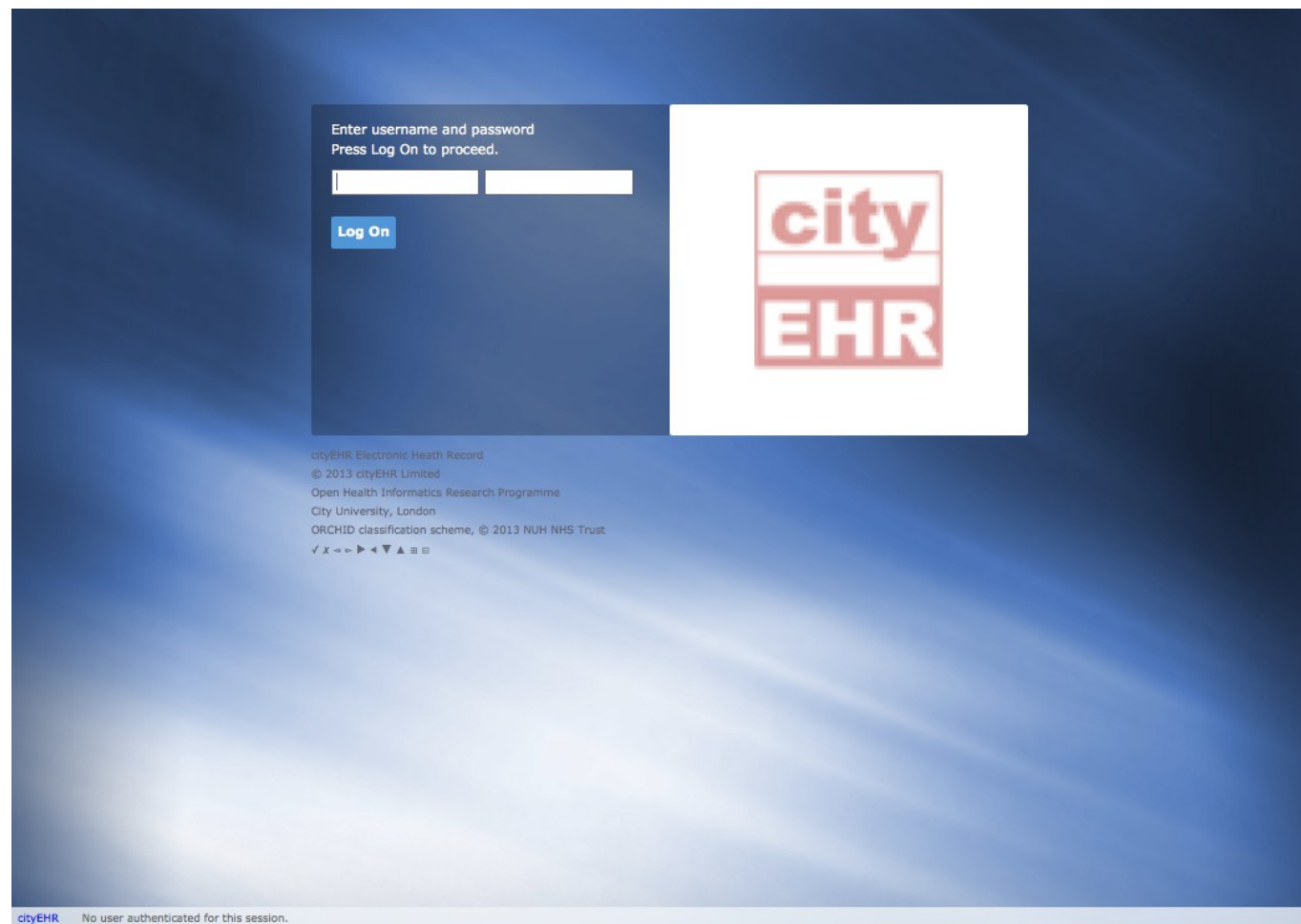
SectionID	Display Name	Layout	PreConditions	Conditions	Contents	H
1	Demographics	Ranked			Entry:KNumber	Section:PatientIdentifiers
2	PatientIdentifiers	Unranked			Entry:NHSNumber	Entry:NorthNumber
3	BasicDemographics	Unranked			Entry:Title	Entry:SouthNumber
4	OtherPatientData	Unranked			Entry:DateOfBirth	Entry:Forename
5	BasicPatientData	Ranked			Section:OsteoporosisScreen	Entry:Gender
6	OsteoporosisPatientDetails	Ranked			Entry:ORCHIDPrimaryDiagnos	Entry:EthnicOrigin
7	OsteoporosisFractureHistory	Ranked			Entry:ORCHIDPrimaryDiagnos	Entry:Diagnosis
8	OsteoporosisLifestyle	Ranked			Entry:PersonalFractureHistory	Entry:FamilyFractureHistory
9	OsteoporosisMedicalConditions	Ranked			Entry:LevelOfMobility	Entry:LevelOfPhysicalActivity
10	OsteoporosisRiskFactors	Unranked			Section:CurrentMedicalCondi	Section:HistoricMedicalConditions
11	OsteoporosisDrugs	Unranked			Section:RiskFactors1	Section:RiskFactors2
12	OsteoporosisBMDData	Unranked			Entry:CurrentMedication	Entry:PreviousMedication
13	OsteoporosisLabResults	Ranked			Entry:BMDData	Entry:BMDData
14	OsteoporosisLabResults	Ranked			Entry:OsteoporosisBoneChem	Entry:OsteoporosisLabTest
15	TendernessAndSwelling	Ranked			Entry:TendernessAndSwelling	Section:OsteoporosisScreen
16	TestosteroneHistory	Unranked		Testosterone	Entry:TestosteronePrep	Entry:TestosteroneStartAge
17	BMDData	Unranked			Entry:BaselineHeight	Entry:TestosteroneOngoing
18	RegularActivity	Unranked			Entry:ActivityLocalWalking	Entry:BaselineBMI
19	SmokingHabits	Unranked			Entry:ActivityGardenDIY	Entry:ActivitySport
20	SizeHistory	Unranked			Entry:CurrentSmoker	Entry:HistoricSmoker
21	CurrentMedicalConditions	Ranked			Entry:HeightAge20	Entry:HeightLoss
22	HistoricMedicalConditions	Ranked			Entry:McMafRiskFactor	Entry:McMafOrCoeliac
23	HRT History	Ranked			Entry:PmhNoRiskFactor	Entry:McMafOrCoeliac
24	Menopause	Unranked			Entry:HRTAge	Entry:PmhHypertension
25	EQD5	Unranked			Entry:HRTPreparation	Entry:HRTAge
26	SF36summary	Unranked			Entry:HRTOngoing	Entry:HRTOngoing
27	SF36a	Ranked			Entry:Menarche	Entry:StillMenstruating
28	SF36b	Ranked			Entry:EQD5Date	Entry:EQD5Date
29	SF36c	Ranked			Entry:SF36date	Entry:SF36scores
30	SF36d	Ranked			Entry:SF3601	Entry:SF3602
31	SF36e	Ranked			Entry:SF3603	Entry:SF3604
32	SF36f	Ranked			Entry:SF3611	Entry:SF3612
33	SF36g	Ranked			Entry:SF3613	Entry:SF3614
34	SF36h	Ranked			Entry:SF3617	Entry:SF3618
35	HADSsummary	Ranked			Entry:SF3620	Entry:SF3621
36	HADSq	Ranked			Entry:SF3623	Entry:SF3622
37	HAQsummary	Ranked			Entry:SF3625	Entry:SF3626
38	HAQdressing	Ranked			Entry:SF3632	Entry:SF3625
39	HAQrising	Ranked			Entry:SF3633	Entry:SF3635
40	HAQeating	Ranked			Entry:SF3634	Entry:SF3636
41	HAQwalking	Ranked			Entry:SF3634	Entry:SF3635
42	HAQaids1	Ranked			Entry:SF3634	Entry:SF3635
43	HAQcategory1	Ranked			Entry:SF3634	Entry:SF3635
44	HAQhygiene	Ranked			Entry:SF3634	Entry:SF3635



cityEHR

Electronic Health Records System

- Web-based EHR
- Open standards
- Clinician led
- One click deployment
- Enterprise scale



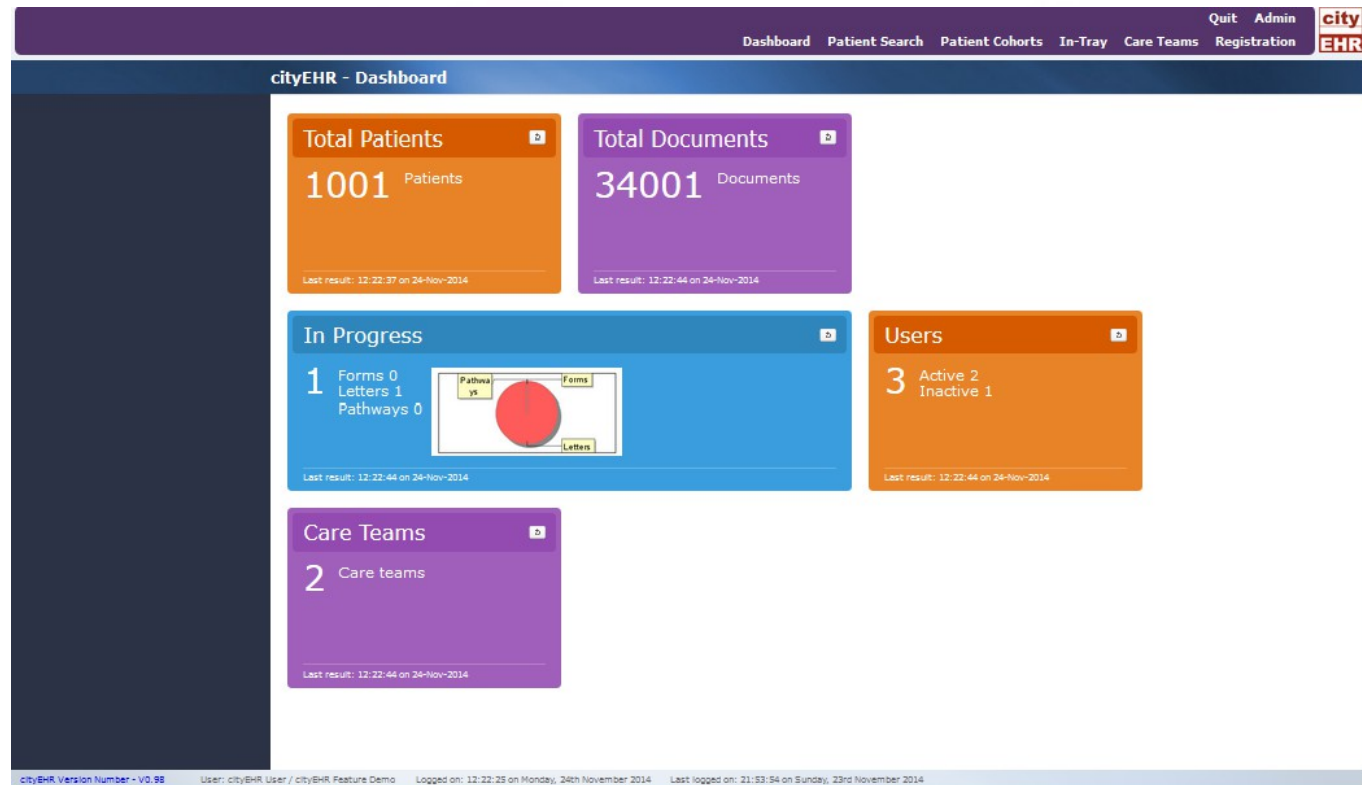
The screenshot shows the login interface for the cityEHR system. It features a dark blue background with a white login form on the left and the cityEHR logo on the right. The login form includes a text prompt, two input fields for username and password, and a blue 'Log On' button. Below the form, there is a block of small text containing copyright and licensing information. At the bottom left, a status bar indicates 'No user authenticated for this session.'

cityEHR Electronic Health Record
© 2013 cityEHR Limited
Open Health Informatics Research Programme
City University, London
ORCHID classification scheme, © 2013 NUH NHS Trust
✓ ✕ ← → ▶ ◀ ▼ ▲ ■ ■ ■

cityEHR No user authenticated for this session.

Dashboard – Cross Patient Information

- Execute any database query (configurable)
- Summary of results
- Charts (Bar, Pie, Dial)



Finding Patients

- Patient search
- Linked to entries in designated CDA registration documents
- Completely configurable
- Recently accessed (from audit log)
- From clinic lists
- From in-patient lists

cityEHR

Quit Admin

Dashboard Patient Search Patient Cohorts In-Tray Care Teams Registration

Recent In-patients

K1473055 - Abernathy
K5954065 - Abernathy
M6152131 - Chumley-Warren
M4426572 - Jones
L4868424 - Hart
M9830530 - Harmon

Patient Search Jones/lars : Search time: PTD.3445 / PTD.115 | Inpatients Only Order by Surname

Patient Id Surname jones Forename lars

Gender -- Select Value --

Day of Birth -- Select Value -- Month -- Select Value -- Year Date

Consultant

Displaying 1 to 1 of 1 patients

Hospital Number	Forename	Surname	Gender	DoB
L3726574	Lars	Jones	Male	28-Jun-1975

cityEHR Version Number - V0.98 User: cityEHR User / cityEHR Feature Demo Logged on: 12:39:23 on Monday, 24th November 2014 Last logged on: 12:22:25 on Monday, 24th November 2014

Full Historic Record

- Full list of stored CDA documents
- From migrated data
- From messages
- Or from input data

The screenshot displays a patient record for Timothy ABERNATHY (Dr) in the cityEHR system. The patient's details include: Born 08-Feb-1979 (34 years), Gender Male, Hospital Number, and NHS Number 1000001356. The interface features a navigation bar with options like Dashboard, Patient Search, Patient Cohorts, In-Tray, Care Teams, and Registration. The main content area shows a list of events under the heading "08-Feb-2013 - Hospital Anxiety and Depression Scale". The left sidebar lists various events, including Rheumatoid Arthritis Clinic (4), Risk Factors (1), Update Patient Demographics (9), Feature Demonstration (17), and Hospital Anxiety and Depression Scale (8). The selected event, dated 08-Feb-2013, displays the following HADS results:

08-Feb-2013 - Hospital Anxiety and Depression Scale

Anxiety Score
15 Moderate

Depression Score
17 Severe

I feel tense or 'wound up'
Most of the time

I still enjoy the things I used to
Not quite as much

I get a sort of frightened feeling as if something awful is about to happen
Yes, but not too badly

I can laugh and see the funny side of things
Not at all

Worrying thoughts go through my mind
A great deal of the time

I feel cheerful
Not often

I can sit at ease and feel relaxed
Usually

I feel as if I am slowed down
Very often

I get a sort of frightened feeling like 'butterflies' in the stomach
Not at all

I have lost interest in my appearance
Definitely

I feel restless as if I have to be on the move
Very much indeed

I look forward with enjoyment to things

cityEHR V0.98 User: cityEHR User Logged on: 07:08:39 on Friday, 22nd November 2013 Last logged on: 21:40:07 on Wednesday, 20th November 2013

Annotating the Historic Record

- Add annotations to historic data
- Configurable structure of annotations
- Stored as HL7 CDA
- Linked to subject document
- With notification to InTray

ABERNATHY, Timothy (Dr) Born 08-Feb-1979 (34 years) Gender Male

Hospital Number NHS Number 1000001356

Quit Admin

Dashboard Patient Search Patient Cohorts In-Tray Care Teams Registration

cityEHR

Events

08-Feb-2013 - Hospital Anxiety and Depression Scale

Date	Type	Comments	Action	Notify
12:21:01 on 22-Nov-2013	Alert	This patient is severely depressed please handle with care	Notify Role	Nurse

Anxiety Score
15 Moderate

Depression Score
17 Severe

I feel tense or 'wound up'
Most of the time

I still enjoy the things I used to
Not quite as much

I get a sort of frightened feeling as if something awful is about to happen
Yes, but not too badly

I can laugh and see the funny side of things
Not at all

Worrying thoughts go through my mind
A great deal of the time

I feel cheerful
Not often

I can sit at ease and feel relaxed
Usually

I feel as if I am slowed down
Very often

I get a sort of frighened feeling like 'butterflies' in the stomach
Not at all

cityEHR V0.98 User: cityEHR User Logged on: 07:08:39 on Friday, 22nd November 2013 Last logged on: 21:40:07 on Wednesday, 20th November 2013

Clinical Data Entry

- All data relationships and behaviour are defined in the information model
- Conditional sections, entries, clusters, elements
- Calculated values (elements)
- Multiple entries
- Pre-filled entries
- Default values
- Constraints
- Hints
- Supporting information
- Required values
- Layout
- Rendition
- Reference data look-up

ABERNATHY, Timothy Born 28-Mar-1979 (34 years) Gender Male
K1476889 NHS Number 1000001356

Dashboard Patient Search Clinic Lists Patient Cohorts

Quit Admin

In Progress New Hide Patient Record Summaries Forms Care Setting: Rheumatology Show

▼ Rheumatology (26)

15-Jul-2013 - HADS

Hospital Anxiety and Depression Scale
Anxiety Score 14 Moderate
Depression Score 9 Mild

I feel tense or 'wound up'	Most of the time
I still enjoy the things I used to enjoy	Not quite as much
I get a sort of frightened feeling as if something awful is about to happen	Yes, but not too badly
I can laugh and see the funny side of things	Not quite so much now
Worrying thoughts go through my mind	From time to time, but not too often
I feel cheerful	Most of the time
I can sit at ease and feel relaxed	Usually
I feel as if I am slowed down	Very often
I get a sort of frightened feeling like 'butterflies' in the stomach	Occasionally
I have lost interest in my appearance	I don't take as much care as I should
I feel restless as I have to be on the move	Very much indeed
I look forward with enjoyment to things	Rather less than I used to
I get sudden feelings of panic	Very often indeed
I can enjoy a good book or radio or TV program	Not often

ORCHID V0.98 User: cityEHR User Logged on: 14:11:52 on Monday, 15th July 2013 Last logged on: 02:57:03 on Monday, 15th July 2013

Graphical Input of ISO-13606 Entry

- Link any image with an ISO-13606 entry
- Define an image map, linking to ISO-13606 elements
- Data input is through click on the image
- Only affects the rendition of the entry
 - All other aspects of the data are identical to form-based renditions

ABERNATHY, Timothy Born 28-Mar-1979 (34 years) Gender Male
K1476889 NHS Number 1000001356

Dashboard Patient Search Clinic Lists Patient Cohorts

In Progress New Hide Patient Record Summaries Forms Care Setting: Rheumatology

Psoriatic Arthritis Clinic
Rheumatoid Arthritis Clinic
SLE Clinic
BATH Indices
DAS 28
DAS 68
Disease Activity Score
Fracture Record
PASI
PsARC
SLEDAI
EQ-5D
HADS
HAQ
Mini Nutritional Assessment
RAND 36-Item Short Form Health Survey
RODNAN
WHOQOL-BREF

15-Jul-2013 - DAS 68

Disease Activity Score

Swollen Joints 6 Tender Joints 4

ESR 45
CRP 65
Visual Analogue Scale 3
DAS Score (ESR) 4.5
DAS Score (CRP) 4.3

ORCHID V0.98 User: cityEHR User Logged on: 14:11:52 on Monday, 15th July 2013 Last logged on: 02:57:03 on Monday, 15th July 2013

Graphical Input of Multiple Entries

- Link any image with an ISO-13606 entry
- Define an image map, linking to one ISO-13606 element
- Data input is through click on the image
- Each click adds a new entry to the record
- Only affects the rendition of the entry
 - All other aspects of the data are identical to form-based renditions

ABERNATHY, Timothy Born 28-Mar-1979 (34 years) Gender Male
K1476889 NHS Number 100001356

Quit Admin
Dashboard Patient Search Clinic Lists Patient Cohorts

Show Patient Record Summaries Forms Care Setting: Rheumatology

15-Jul-2013 - Fracture Record

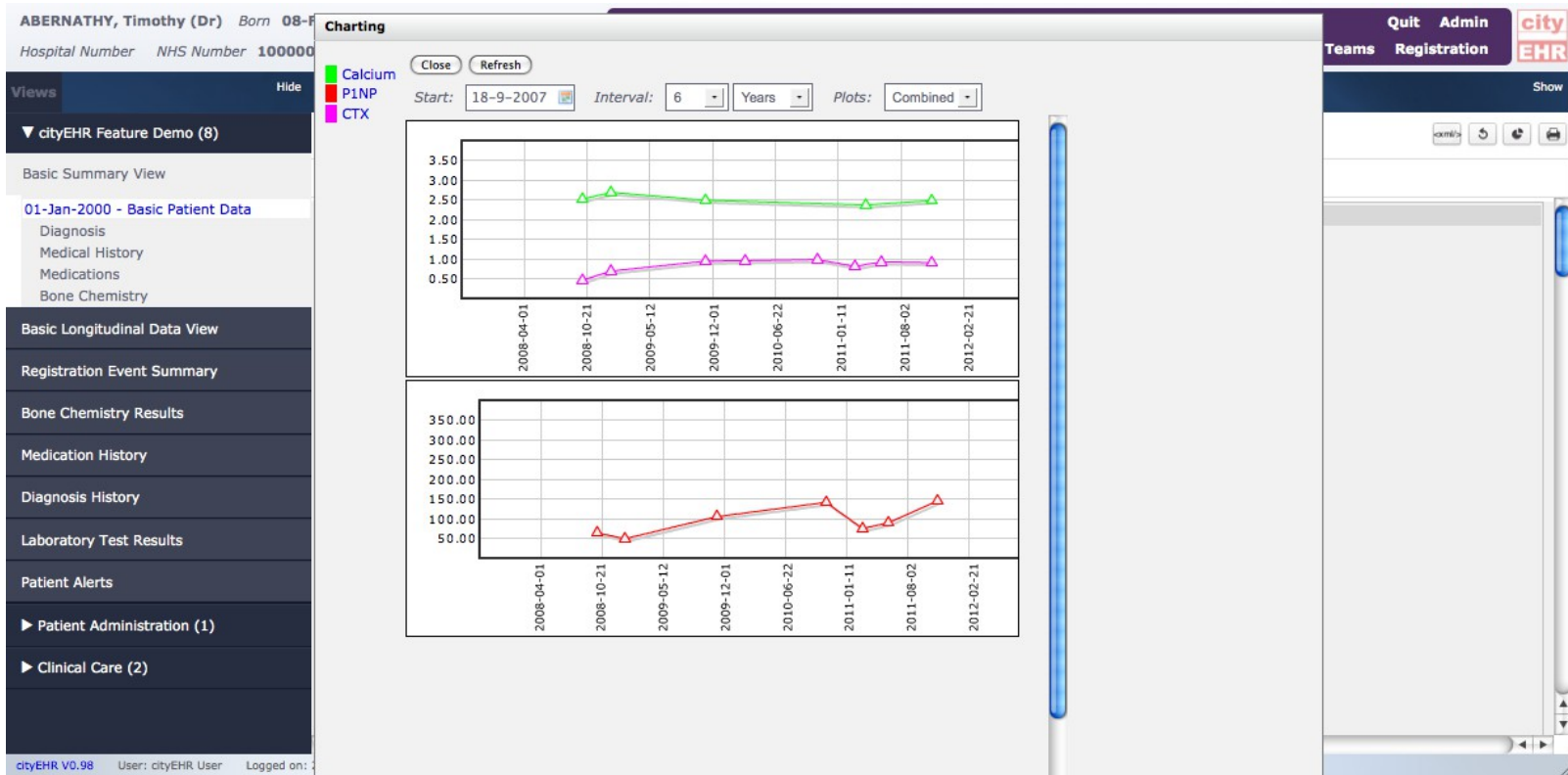
Fractures

Fracture Site	Type	Trauma level
01-7-2013 Left Shaft Humerus	-- Select --	-- Select --
01-7-2013 Left Maxilla	-- Select --	-- Select --
01-7-2013 Right Phalanges (hand)	-- Select --	-- Select --

ORCID V0.98 User: cityEHR User Logged on: 14:11:52 on Monday, 15th July 2013 Last logged on: 02:57:03 on Monday, 15th July 2013

Charts of Historic Data

- Available for recognised data patterns
- For an longitudinal data sets
- Generated as SVG graphics
- As trends or interval plots
 - Laboratory test results
 - Start and stop dates for medications



Letters – Integrated Part of the Record

- Created as CDA documents
- Using same modelling tools as other documents
- Stored as HL7 CDA
- Printed (exported) as
 - PDF
 - MS Word

The screenshot displays a patient record interface for **BREAM, Barnabus (Mr)**, born 03-Sep-2012 (12 months), Gender Male. The interface includes a navigation menu with options like "In Progress", "Add New Letter", "Patient Record", "Summaries", "Enter Patient Data", and "Letters". The "Letters" section is active, showing a list of letters from 20-Aug-2013 to 15-May-2013. A preview window shows a letter dated 20-Aug-2013, titled "20-Aug-2013 - Patient Letter". The letter content includes:

OXFORD

Consultants: Dr M. Kassim Javaid
Clinical Assistant: Dr Sally Hope
Clinical Nurse Team: Kerri Rance, Carol W
Clinical DXA: Julie Aston; HCA: Leonora L

Mr Bream
21 Basham Street
Oxford
OX2 7HJ

Dear Mr Bream

You were recently seen by cityEHR User from fractured your Femur

This letter is a summary of your treatment plan

The preview window also shows a PDF document titled "document-247.pdf (page 2 of 2)" with a sidebar and search bar. The PDF content includes:

Patient id: 1234567892

What are my choices to reduce fracture risk?

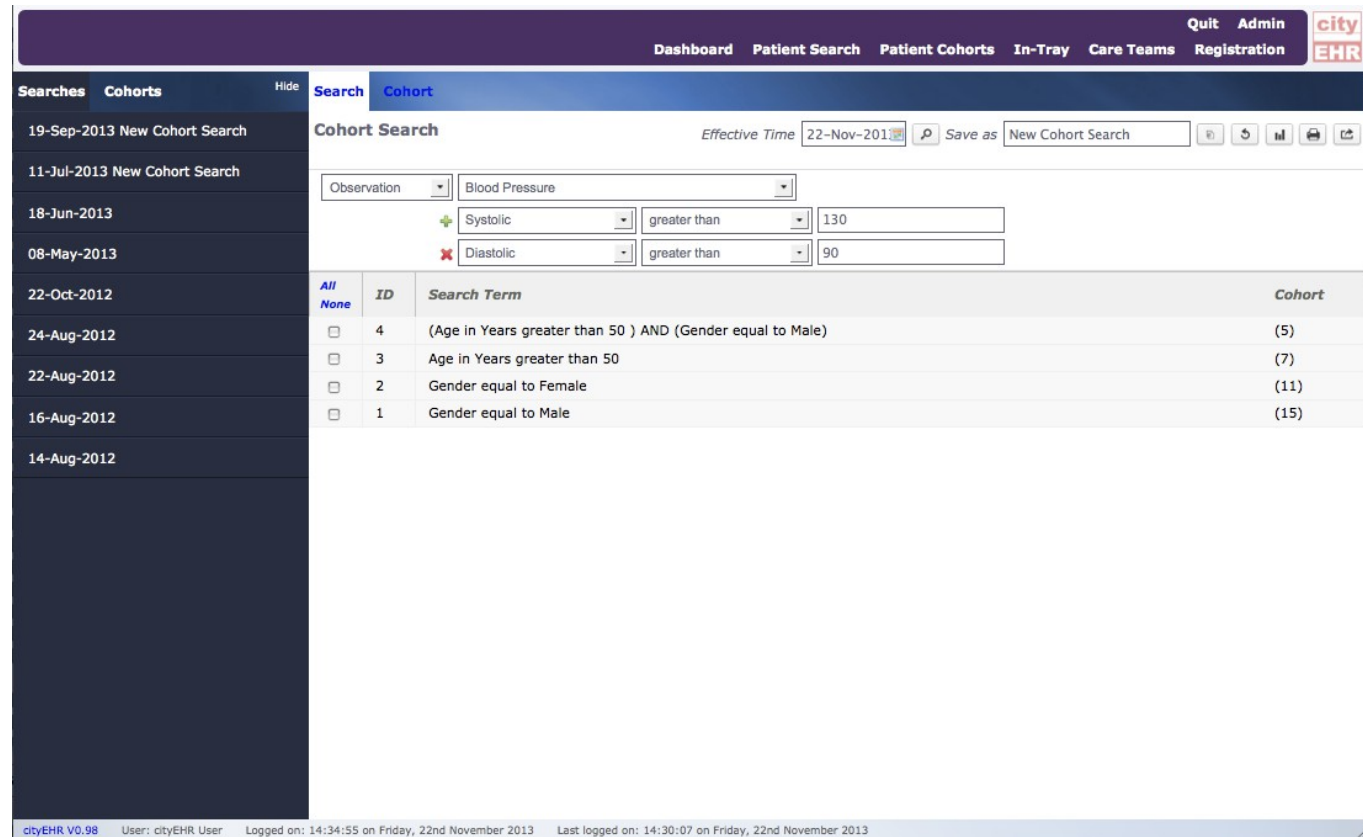
The most important choices for you are:

- #ORCHID-Class:Drugs:risedronate drug therapy for 3 years.
This medication is taken with a large glass of tap water once a week after fasting overnight at least half an hour before any food, drink or other medication. You must also remain upright or standing for this half hour. Please read the information leaflet carefully as it is important you follow the instructions exactly to get benefits from your treatment.
- You need calcium to make sure your medication works to strengthen your bones.
No specific recommendations for you
- Vitamin D is needed for your medication to work to strengthen your bones.
Your level is low and we will provide you with high strength Vitamin D tablets that you need to take as per the instructions on the bottle. We have given you one years supply. If you have been recommended Calcium and Vitamin D tablets, continue them in addition to these new tablets.
- No specific recommendations for you
- No specific recommendations for you
- No specific recommendations for you

Page [2] of [2]

Secondary Uses of Clinical Data

- Cohort search using terms built from the data dictionary
- Use entry/element in clinical context
- Combine cohorts
- Export cohorts, with specified data sets
- as HL7 CDA
- as spreadsheet
- (anonymised)



The screenshot displays the CityEHR Patient Cohorts interface. The top navigation bar includes links for Dashboard, Patient Search, Patient Cohorts, In-Tray, Care Teams, and Registration. The main content area is titled "Cohort Search" and shows a search configuration for "Blood Pressure". The search criteria are defined as "Systolic" greater than 130 and "Diastolic" greater than 90. The results table lists four cohorts with their respective search terms and patient counts.

All None	ID	Search Term	Cohort
<input type="checkbox"/>	4	(Age in Years greater than 50) AND (Gender equal to Male)	(5)
<input type="checkbox"/>	3	Age in Years greater than 50	(7)
<input type="checkbox"/>	2	Gender equal to Female	(11)
<input type="checkbox"/>	1	Gender equal to Male	(15)

CityEHR V0.98 User: cityEHR User Logged on: 14:34:55 on Friday, 22nd November 2013 Last logged on: 14:30:07 on Friday, 22nd November 2013

Care Pathways as CDA Documents

- Pathways modelled as CDA documents
- Using same modelling tools as other documents
- Stored as HL7 CDA
- In progress
- and when complete
- forms part of the record

The screenshot displays the cityEHR interface for a patient named Timothy ABERNATHY (Dr), born 08-Feb-1979 (34 years), male. The patient's hospital number is blank, and their NHS number is 1000001356. The interface shows a navigation menu with options like Dashboard, Patient Search, Patient Cohorts, In-Tray, Care Teams, and Registration. The current view is '22-Nov-2013 - Manage Weight In Progress'. The left sidebar lists actions: Manage Weight, Enter Data, Follow Up, and Monitor Patient. The main content area is divided into sections: 'Enter Data' with a status of 'Charted' and outcome 'To be confirmed'; 'Enter BMI Data' with a red warning banner stating 'Only enter these data if you are sure you know what you are doing' and fields for Role, Delay (days), Status, and Outcome; and 'Follow Up' with a green banner stating 'BMI is 20.2' and fields for Status, Outcome, Role, Delay (days), Status, and Outcome. The footer shows the user is logged in as 'cityEHR User' on Friday, 22nd November 2013.



In-Tray – Collaboration for Care Teams

- List of notifications for the user
- Can be actions in pathways
- Or annotations on events
- Click directly through to the patient record

The screenshot displays the 'In-Tray' section of the cityEHR system. At the top, a navigation bar includes 'Dashboard', 'Patient Search', 'Patient Cohorts', 'In-Tray', 'Care Teams', 'Registration', 'Quit', and 'Admin'. The 'cityEHR' logo is in the top right corner. Below the navigation bar, there are tabs for 'New', 'In Progress', and 'Old', with a 'Hide' button. The main content area is titled 'In-Tray - cityEHR User' and contains a list of actions on the left and patient details on the right.

Actions (3)

- 19:53:45 on 19-Nov-2013 K1476889 Abernathy Enter BMI Data in Manage Weight
- 19:40:19 on 19-Nov-2013 K1476889 Abernathy Enter BMI Data in Manage Weight
- 19:35:36 on 19-Nov-2013 K1476889 Abernathy Enter BMI Data in Manage Weight

Patient Information:

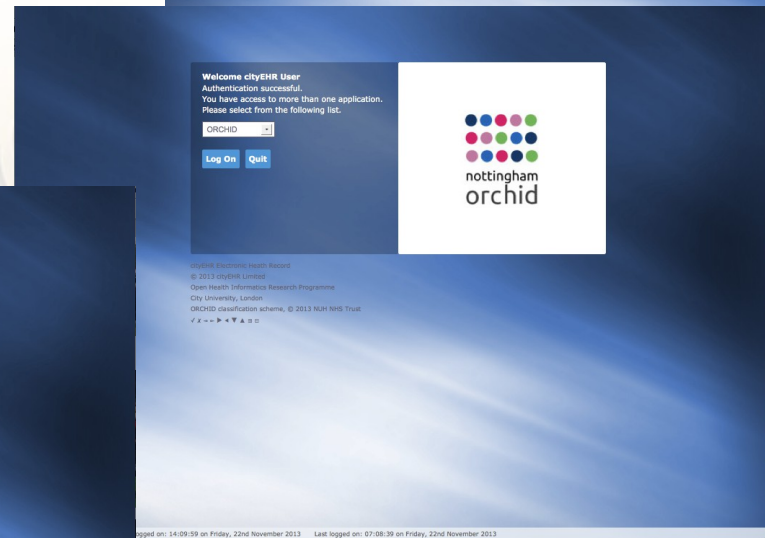
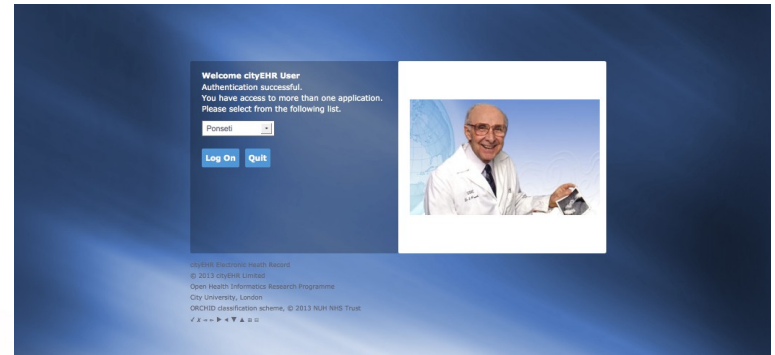
ABERNATHY, Timothy (Dr) Born **08-Feb-1979 (34 years)** Gender **Male**
Hospital Number NHS Number **1000001356**

This Action was recorded at: 19:53:45 on 19-Nov-2013
Notification for:
Notification for action

cityEHR V0.98 User: cityEHR User Logged on: 07:08:39 on Friday, 22nd November 2013 Last logged on: 21:40:07 on Wednesday, 20th November 2013

NHS Implementations

- Ponseti database – club foot clinics
 - Chelsea and Westminster
 - Manchester Children's Hospital
- ORCHID – clinical data for biobank
 - Nottingham University Hospital
- Elfin – pathways for fracture prevention
 - Nuffield Orthopaedic Centre, Oxford





cityEHR

- cityEHR – Open source (LGPL) electronic health records
 - john.chelsom.1@city.ac.uk
 - john.chelsom@seveninformatics.com



cityEHR

Open Health Informatics for Electronic Health Records