Unlocking Medical Records with Natural Language Processing

LabKey User Conference
October 1st, 2015
Informatics at Fred Hutch – Overview of the Cancer Consortium
What is HIDRA?

Hutch Integrated Data Repository and Archive

- A broad and comprehensive database that combines patients’ clinical records, tumor genetics and molecular data and related research information with the aim of eventually helping doctors choose the best targeted treatments for people with cancer.

- Hardware and software “plumbing” that bring multiple databases and data sources together into one high security environment.

- A data resource for the Consortium.

- A development platform for custom applications like Argos.
HIDRA Environment: Conceptual Diagram

**Data Sources**
- UW CDR
- Seattle Children’s
- CSS
- Archive (Access, etc.)

**HIDRA CORE Data Repository and Archive**
- Aligned Data from Multiple Sources (CAISIS Data Model)
  - Assays
  - Subjects
  - Studies
  - Specimens

**Curated Cubes**
(i.e., reports, views into the data, etc.)

**Systems**
- ARGOS
- CAISIS
- Gateway
- CTMS*
- Oncoscape*
- SCCA Oasis*

* Denotes systems managed outside of CIT Informatics
**HIDRA by the Numbers**

**Patients**
- 335,000 total patients

**Size**
- 809 million rows of data
- 380 Gb of total storage space

**Example Data Elements**
- 150 million lab chemistry results from 26 million orders
- 48 million encounter events
- 3 million diagnostic imaging orders and their results
Research Tools

Caisis
- Provides a single-patient view of data
- Allows clinical data entry and update
- Is based on a cancer data model
- Receives data from HIDRA feeds
- Is the source of data for Argos

Argos
- A self-service reporting interface allowing researchers to access and explore the rich information currently collected, linked and stored in HIDRA databases
- Balances easy access with good security controls
- Developed in collaboration with LabKey Software.
- Presents aggregate data stored in Caisis, whether it was entered by abstractors, received from HIDRA feeds or imported from custom databases maintained by disease groups
### Data Elements Feeding into CAISIS from HIDRA

<table>
<thead>
<tr>
<th>Demographics</th>
<th>Diagnostics</th>
<th>Pathology</th>
<th>Appointments</th>
<th>Physicians</th>
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<td>Notes (in text blob)</td>
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<td>Birth Place</td>
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Fred Hutch Research Systems & Data - today

Cancer Consortium Patients Data

UW Clinical Data Repository

UW EMR, Lab Systems, EPIC, PowerPath, etc.

SCCA

HIDRA

Data Requests

Report

Analyst

Caisis provides:
- Single-patient medical record view
- Form interface for abstraction of medical records
- Labs and Demographic data from HIDRA feeds

Abstractor

Copy of CaisisMAINDB

CaisisMAIN

Argos

Argos provides aggregate patient data views of data available in CaisisMAIN

Tools for EMR-based Research
Fred Hutch Research Systems & Data - future

Cancer Consortium Patients Data

UW Clinical Data Repository

HIDRA

CaisisMAIN

Argos

Data Quality Control
- Validation
- Input

NLP Abstraction Pipeline

Medical Record Data

UW EMR, Lab Systems, EPIC, PowerPath, etc.

SCCA

Copy of CaisisMAINDB

Data Feeds to Other Systems

Analysts

Report Data Requests

Researchers

Researchers

Researchers

Caisis provides:
- Single-patient medical record view
- Form interface for abstraction of medical records
- Labs and Demographic data from HIDRA feeds

Argos provides aggregate patient data views of data available in Caisis

Tools for EMR-based Research
The Problem – Scaling Up

- Currently, the majority (65-80%) of the data elements needed for clinical and translational research in cancer can only be found in unstructured narrative reports.

- Manually abstracting clinical data for all historical, current, and future patients is time and resource intensive and ultimately is not scalable.
MATERIALS RECEIVED:

<table>
<thead>
<tr>
<th>Label</th>
<th>Consult Accession No</th>
<th>Blocks/Slides</th>
<th>Description</th>
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<tbody>
<tr>
<td>A</td>
<td></td>
<td>0B,9S</td>
<td>Colon, right hemicolectomy</td>
</tr>
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</table>

FINAL DIAGNOSIS:

A) Portion of terminal ileum, cecum, and ascending colon, resection: Invasive, moderately differentiated colonic adenocarcinoma. Please see the Cancer Summary below.

SUMMARY CANCER DATA:

Specimen and Tumor Location

- Specimen type: Right hemicolectomy
- Tumor site: Cecum (C18.0)

Characteristics and Extent of Neoplasm

- Histologic type: Adenocarcinoma (81403)
- Histologic grade: Low-grade (well to moderately differentiated: >50% gland formation)
- Tumor size: Greatest diameter: 5cm
- Tumor perforation (macroscopic): Not identified
- Microscopic tumor extent:
  - Tumor invades through muscularis propria but does not penetrate any peritoneal surface
- Tumor deposits: Not identified
- Lymphatic [small vessel] Invasion (L): Not identified
- Venous [large vessel] Invasion (V): Not identified
- Perineural invasion: Absent

Final Surgical Resection Margins

- Grossly positive margin(s): None
- Microscopically positive margin(s): None

Lymph Node Status

- Node summary: Nodes with carcinoma: 0 / Total nodes examined: 15
- Minimum Pathologic Stage (AJCC, 7th ed., 2010)
  - Primary tumor (pT): pT3: Tumor invades through the muscularis propria into pericolorectal tissues
  - Regional lymph nodes (pN): pN0: No regional lymph node metastasis

Other Findings
Medical oncology clinic note

IDENTIFICATION

a 70-year-old gentleman with a history of a peripheral T-cell lymphoma, history of prostate cancer, a history of a T3N0M0 colon cancer resected on [REDACTED] who comes in for surveillance.

INTERVAL HISTORY

[REDACTED] was treated by [REDACTED], MD, for peripheral T-cell lymphoma and had an autologous stem cell transplant followed by a nonmyeloablative allogeneic transplant in [REDACTED] and he has been in complete remission since that time. He has also had treatment for prostate cancer, clinical stage T1c, Gleason 3+3 disease in [REDACTED] 2008, treated with brachytherapy and since then his PSA has been minimally detectable.

[REDACTED] had a right partial colectomy on [REDACTED] with a pathologic finding of an adenocarcinoma, stage pT3NM0 with a 5 cm primary tumor, 0/15 lymph nodes involved with cancer, and negative surgical margins. He was not treated with adjuvant therapy as it was not indicated.

[REDACTED] continues to do well. He continues to play golf, feels well, has not developed any new issues. He saw [REDACTED] with no new recommendations. He had a colonoscopy in [REDACTED] which showed no lesions and a followup was recommended in [REDACTED].

MEDICATIONS
Levothyroxine 137 mcg p.o. once a day
The Problem

- Efforts to implement templated notes are underway, but changes in clinical workflow are often slow and difficult to adopt.

- Templating will provide access to many discrete data elements, but it will not provide access to historical data in narrative form and it's not reasonable to expect that all clinical data entry will be templated.
Because of the necessary protection of private data there is
- limited cross institutional collaboration
- very few annotated data sets for training and benchmarking
- insufficient common conventions and standards in terminology
- over-fitting to specific applications and institutions

While some data sets and collaboration have been encouraged by shared tasks, the resulting systems have had limited carryover to industry
The Landscape – Current Options in Clinical NLP

- Commercial
  - Black box systems
  - Do not allow for development and improvement over time

- Open Source
  - Lack support for setup and implementation
  - Require specific knowledge and skill set to use and customize
  - Not optimized for our needs as a cancer center
  - Do not provide a single platform for automated processing, manual verification, storage, and tracking on an enterprise level

- We're designing a clinical data pipeline that will serve as a platform, not only for automated information extraction using natural language processing algorithms, but also manual data abstraction and the verification of extracted elements.

- By using the existing manual abstraction workflow we can
  - iteratively create a larger training corpus for NLP algorithms
  - decrease the time and effort of manual processes
  - increase the volume and variety of clinical data reaching researchers, administrators, and providers
The Solution – Clinical Data Pipeline Design

- HIDRA
- Staging
- LabKey Server
- NLP Engine
- Other Data Storage
- Casis

Staging
The Solution – A Single Platform for All Workflows
The Solution – A Single Platform for All Workflows

- **NLP Engine Abstraction**
- **Assign Abstractions**
  - numAbstractors == 0?
  - numAbstractors == 2?
  - numAbstractors > 0?
  - Take into account the need for an abstractor to have context (multiple documents for a patient)
- **Manual Abstraction**
  - Input to manual process is NLP engine output
- **Compare Abstractions**
  - Nothing to do if only one abstraction done
- **Review Abstraction**
  - yes review?
  - yes revision?
- **Compute Statistics**
- **Data Abstracted**

This could be just extraction of text with no abstraction algorithm
The Solution – NLP Pipeline Design

- Hierarchical system design allows us to customize parsing for different clinical document types

- Modular algorithm design should better account for extensibility and growth over time
  - New parsers can be created when formatting or source systems change
  - New algorithms can be created when training data is available and/or new research questions arise
The Solution - NLP Pipeline Design

Input/Arguments → NLP Engine → Output/Results

Pathology
- Pathology Report Parser
- General Pathology Modules & Resources

Lung
- Lung Specific Pathology Modules & Resources

Clinic Notes
Cytogenetics
Radiology
Surgery

Breast
Colorectal
Brain
Prostate
Sarcoma
The Big Picture

use automation to speed up manual work

apply NLP algorithms
verify results
create training data

use manual workflow to improve automation
# HIDRA Overall Program Schedule

<table>
<thead>
<tr>
<th>Year</th>
<th>Phase</th>
<th>Description</th>
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</thead>
</table>
| 2013 | FY13  | HIDRA Core Phase 1  
Pipeline, Infrastructure, Data Feeds, Security, Operations |
| 2014 | FY14  | Argos 1.0  
Brain Pilot Design |
| 2015 | FY15  | Argos 2.0  
Visualization, Report building |
| 2016 | FY16  | NLP, Additional Disease Groups |

## Phase 2
More Data, Analytics Tools, Security

## Phase 3
More Data, Analytics Tools

## Phase 4
More Data Sources

### NLP Algorithm Development/ Disease Group Pilots
Design, Storyboarding, Specification

### Argos 3.0
Disease Group Expansion

### Argos 4.0
Disease Group Expansion

### NLP Prototype
Lung Pathology

### NLP Application 1.0
Multiple algorithms

- **March 2015**: Argos Consortium Launch
- **June 2015**: HIDRA Platform in Production
- **September 17**: Thoracic and Head and Neck
- **November**: HIDRA Core Repository Populated
<table>
<thead>
<tr>
<th>LabKey</th>
<th>Fred Hutch</th>
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<tbody>
<tr>
<td>• Developer(s)</td>
<td>• NLP Engineer</td>
</tr>
<tr>
<td>• Test Dev</td>
<td>• Abstractors</td>
</tr>
<tr>
<td>• Admin/Management</td>
<td>• Project Sponsors</td>
</tr>
<tr>
<td></td>
<td>• Project Manager</td>
</tr>
<tr>
<td></td>
<td>• Interns</td>
</tr>
<tr>
<td>Roughly 1.25 FTE annually</td>
<td>Roughly 2.0 FTE annually</td>
</tr>
</tbody>
</table>
The Solution – A Demonstration in two parts
The Raw Text Pathology Reports

NULL

FINAL DIAGNOSIS:
A) Gallbladder, cholecystectomy: Gallbladder and one lymph node negative for carcinoma.

NULL

B) Right liver, hemihepatectomy:
1. Metastatic adenocarcinoma, 7.5 cm and 1.8 cm, 99% necrotic. Necrotic material is present at the liver resection margin (slide B5). The inked liver resection margin appears negative for viable carcinoma.
2. The background liver has mild macrosteatosis (15%), minimal non-specific portal based inflammation, likely secondary to mass effect, with no fibrosis.

NULL

C) Liver, new posterior margin, excision: Liver parenchyma is negative for carcinoma.

NULL

D) Right colon and terminal ileum, hemolectomy: Colonic adenocarcinoma, moderately-differentiated, see Summary Cancer Data.

NULL

NULL

SUMMARY CANCER DATA:
Specimen and Tumor Location
Specimen type: Right hemolectomy
Specimen length: 36 cm
Tumor site: Right (ascending) colon (C18.2)
Characteristics and Extent of Neoplasm
Histologic type: Adenocarcinoma (81403)
Histologic grade: Low-grade (well to moderately differentiated; >50% gland formation)
Tumor size: Greatest diameter: 5.3 cm
Tumor perforation (macroscopic): Not identified
Microscopic tumor extent:
Tumor invades through muscularis propria but does not penetrate any peritoneal surface
Tumor deposits: Not identified
Lymphatic [small vessel] Invasion (L): Not identified
Venous [large vessel] Invasion (V): Not identified
Perineural invasion: Absent
Treatment effect: Extensive residual cancer
NLP Pipeline Demo
### Data Pipeline

**Show:** Running, Errors, All

**PROCESS AND IMPORT DATA**

- Status
- Created
- Description
- Info

*No data to show.*

---

### NLP Reports

<table>
<thead>
<tr>
<th>View Results</th>
<th>Modify Results</th>
<th>Abstract Data</th>
<th>Report Id</th>
<th>Job Run Id</th>
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*Powered by LabKey Test*
### NLP engine invocation and results

Choose an existing protocol or define a new one.

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<thead>
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<th>Analysis Protocol:</th>
<th>Single Simpson NLP TSV</th>
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<tbody>
<tr>
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<tr>
<td>Protocol Description:</td>
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<tr>
<td>File(s):</td>
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</table>

```xml
<?xml version="1.0"?>
<owl>
<!-- Override default parameters here. -->
</owl>
```

Parameters:

- **Save protocol for future use**
- **ANALYZE**
- **CANCEL**
LabKey Server

NLP

NLP engine invocation and results

Choose an existing protocol or define a new one.

Analysis Protocol: <New Protocol>

Protocol Name: single_simpson.nlp.tsv

Protocol Description:

File(s):

Parameters:

Save protocol for future use

ANALYZE  CANCEL
NLP engine invocation and results

Choose an existing protocol or define a new one.

Analysis Protocol: LKUC_Argos_NLP
Protocol Name: Run pathology NLP pipeline
File(s): single_simpson.nlp.tsv
Parameters:
<br />
Save protocol for future use

ANALYZE  CANCEL
Job Status

Created 2015-10-01 16:08
Modified 2015-10-01 16:08
Email adam@muuch.com
Status COMPLETE

File Path C:/nlp/nlpEngineInvocation/LKUC_Argos_NLP/single_simpson.log
Files single_simpson.log

---

single_simpson.log

INFO : Starting to run task 'org.labkey.api.pipeline.CmdCommandTask:nlpEngineCommand' at location 'webserver'
01 Oct 2015 16:00:54,703 INFO : Copying C:\nlp\nlpEngineInvocation\LKUC_Argos_NLP\nlpEngineInvocation.xml to C:\nlp\nlpEngineInvocation\LKUC_Argos_NLP\single_simpson.work\nlpEngineInvocation.xml
01 Oct 2015 16:00:54,768 INFO : python output
01 Oct 2015 16:00:54,781 INFO : ---------
01 Oct 2015 16:00:54,786 INFO : Working directory is C:\nlp\nlpEngineInvocation\LKUC_Argos_NLP\single_simpson.work
01 Oct 2015 16:00:54,797 INFO : running: C:\Program Files (x86)\Python27\python c:\nlp\argos_nlp_104\nlp_engine.py -f ...\single_simpson.nlp.tsv -g lung -t pathology -o single_simpson.nlp.json
01 Oct 2015 16:00:56,191 INFO : Moving C:\nlp\nlpEngineInvocation\LKUC_Argos_NLP\single_simpson.work\single_simpson.nlp.json to C:\nlp\nlpEngineInvocation\LKUC_Argos_NLP\single_simpson.nlp.json
01 Oct 2015 16:00:56,205 INFO : Successfully completed task 'org.labkey.api.pipeline.CmdCommandTask:nlpEngineCommand'
01 Oct 2015 16:00:56,247 INFO : Starting to run task 'org.labkey.api.exp.pipeline.XarGeneratorTask' at location 'webserver'
01 Oct 2015 16:00:56,254 INFO : Checking files referenced by experiment run
01 Oct 2015 16:00:56,809 INFO : Experiment run 'nlp/single_simpson (LKUC_Argos_NLP)' complete
01 Oct 2015 16:00:57,313 WARN : nlpEngine reported the following errors in this run.
01 Oct 2015 16:00:57,316 WARN : Error Type: Warning Message: Output directory already existed at progress runtime. It was not empty and was deleted
01 Oct 2015 16:00:57,360 INFO : Importing C:\nt\single_simpson\SM-16-04011.txt for jobId 7
01 Oct 2015 16:00:57,438 INFO : Successfully completed task 'org.labkey.api.exp.pipeline.XarGeneratorTask'
** DEMOGRAPHICS DRAWN FROM PATHOMORPHOLOGY REPORT **

** PATIENT: VAN HOUTEN, MILHOUSE **

** MRN: 123456789 (Springfield Medical Center) **

** DOB: Feb 30 1045 **

** SEX: M **

** CASE: SU-16-0111 **

** COLLECTED: Feb 27 2016 **

** RECEIVED: Apr 22 2016 **

** MATERIALS RECEIVED: **

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<th>Label</th>
<th>Accession No</th>
<th>Blocks/Slides Description</th>
</tr>
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<tbody>
<tr>
<td>A</td>
<td>0514-1050</td>
<td>Colon, right hemicolecotomy</td>
</tr>
</tbody>
</table>

** FINAL DIAGNOSIS: **

A) Marylin Monroe Memorial Hospital, Springfield, ST; 0514-01050 (6/27/2016)

Portion of terminal ileum, cecum, and ascending colon, resection, invasive, moderately differentiated colonic adenocarcinoma. Please see the Cancer Summary below.

** SUMMARY CANCER DATA: **

- **Specimen and Tumor Location**
  - Specimen type: Right hemicolecotomy
  - Tumor site: Cecum (C18.0)
  - Characteristics and extent of Neoplasm:
    - Histologic Type: Adenocarcinoma (81400)
    - Histologic grade: Low-grade (well to moderately differentiated; >50% gland formation)
  - Tumor size: Greatest diameter: 5cm
  - Tumor perforation (macroscopic): Not identified
  - Microscopic tumor extent: Tumor invades through muscularis propia but does not penetrate any peritoneal surface
  - Tumor deposits: Not identified
  - Lymphatic [small vessel] Invasion: Not identified
  - Venous [large vessel] Invasion: Not identified
  - Peri-tumoral Invasion: Absent
  - Final Surgical Resection Margins: Grossly positive margin(s): None
  - Microscopically positive margin(s): None
  - Node Status: Nodes with carcinoma: 0
  - Total nodes examined: 15

** Minimum Pathologic Stage (AJCC, 7th ed., 2010) **

- Primary tumor (pT): pT3: Tumor invades through the muscularis propia into pericolorectal tissues
- Regional lymph nodes (pN): pN0: No regional lymph node metastasis
- Other findings: Tumor-Infiltrating lymphocytes per high-power field: 1
- Peri-tumoral lymphocytic response: Mild/Moderate (up to 2 aggregates/section)
- Additional pathological findings: Adenoma(s)

** SY/pvt **
FINAL DIAGNOSIS:
A) Marvin Monroe Memorial Hospital, Springfield, IL, 0514-01059 (02/07/2016)
Portion of terminal ileum, cecum, and ascending colon, resection. Invasive, moderately differentiated colon adenocarcinoma. Please see the Cancer Summary below.

SUMMARY CANCER DATA:
- Specimen and Tumor Location: Right hemicolectomy
- Characteristics and Extent of Neoplasm: Colon adenocarcinoma (81003)
- Histologic grade: Low-grade (well to moderately differentiated; >50% gland formation)
- Tumor size: Greatest diameter: 5cm
- Tumor permeation (macroscopic): Not identified
- Microscopic tumor extent: Tumor invades through muscularis propria but does not penetrate any peritoneal surface
- Tumor deposits: Not identified
- Lymphatic [small vessel] Invasion (L): Not identified
- Venous [large vessel] Invasion (V): Not identified
- Peritoneal Invasion: Absent
- Final Surgical Resection Margins: Grossly positive margin(s): None
- Microscopically positive margin(s): None
- Lymph Node Status: Node summary: Nodes with carcinoma: 0 / Total nodes examined: 15
- Primary tumor (pt): T3: Tumor invades through the muscularis propria into pericolonic tissues
  Regional lymph nodes (pN): pN0: No regional lymph node metastasis
- Other findings: Tumor-infiltrating lymphocytes per high-power field: 1
- Peri-Tumoral lymphocytic response: Mild/Moderate (up to 2 aggregates/section)
- Additional pathological findings: Adenoma(s)

SY/pwt

__________________________

CLINICAL DATA:
Malignant neoplasm of rectosigmoid junction. The case is for review. The patient will be seen by Dr. Nick Riviera at Springfield GI Clinic.

Salma Bouvier MMBS
GT Path Fellow
04/21/2016
Ned M Flanders MD, PhD
** DEMOGRAPHICS DRAWN FROM PATIENCY REPORT **

** PATIENT: ** VANOHE, MNCOLSE 

** MRN: ** 12345678 (Springfield Medical Center)

** DOB: ** Feb 10 2045

** SEX: ** M

** CASE: ** 98-08-99111 COLLECTED: Feb 27 2016 RECEIVED: April 22 2016

MATERIALS RECEIVED:

- Label: Consult

- Accession No: 08210

- Blocks/Slides Description: Colon, Right Hemicolectomy

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** FINAL DIAGNOSIS:**

A) Mayo Clinic Memorial Hospital, Springfield, CT: O514-01059 (02/27/2016)

Portion of terminal ileum, cecum, and ascending colon. Resection: Invasive, moderately differentiated colonic adenocarcinoma. Please see the Cancer Summary below.

** SUMMARY CANCER DATA:**

Specimen and Tumor Location

- Specimen type: Right Hemicolectomy
- Tumor site: Cecum (C18.9)
- Characteristics and Extent of Neoplastic
- Histologic Type: Adenocarcinoma (D1403)
- Histologic Grade: Low-grade (well to moderately differentiated; >50% gland formation)
- Tumor size: Greatest diameter: 5 cm
- Tumor perforation (macroscopic): Not identified

- Microscopic tumor extent:
  - Tumor invades through muscularis propria but does not penetrate any peritoneal surface
  - Tumor deposits: Not identified
  - Lymphatic [small vessel] Invasion (L): Not identified
  - Venous [large vessel] Invasion (V): Not identified
  - Perineural Invasion: Absent
  - Final Surgical Resection Margins: Grossly positive margin(s); None
  - Microscopically positive margin(s): None

- Lymph Node Status: Nodes with carcinoma: 0

- Total nodes examined: 15

- Minimum Pathologic Stage (AJCC, 7th ed., 2010)

- Primary tumor (pT): pT3: Tumor invades through the muscularis propria into periportalcolectal tissues
- Regional lymph nodes (pN): pN0: No regional lymph node metastasis

- Other Findings:
  - Tumor-Infiltrating lymphocytes per high-power field: 1
  - Peri-tumoral lymphocytic response: Mild/Moderate (up to 2 aggregates/section)

- Additional pathological findings: Adenoma(s)
NLP Pipeline Demo
The Pathology Results in Caisis
The Pathology Results in Argos
THANK YOU