Bringing Healthcare Analytics to Point-of-Care

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Bio

Peter Li, PhD

- Background

  Systems Architect
  Genome Scientist
  Bioinformatician
  Clinical Informatician

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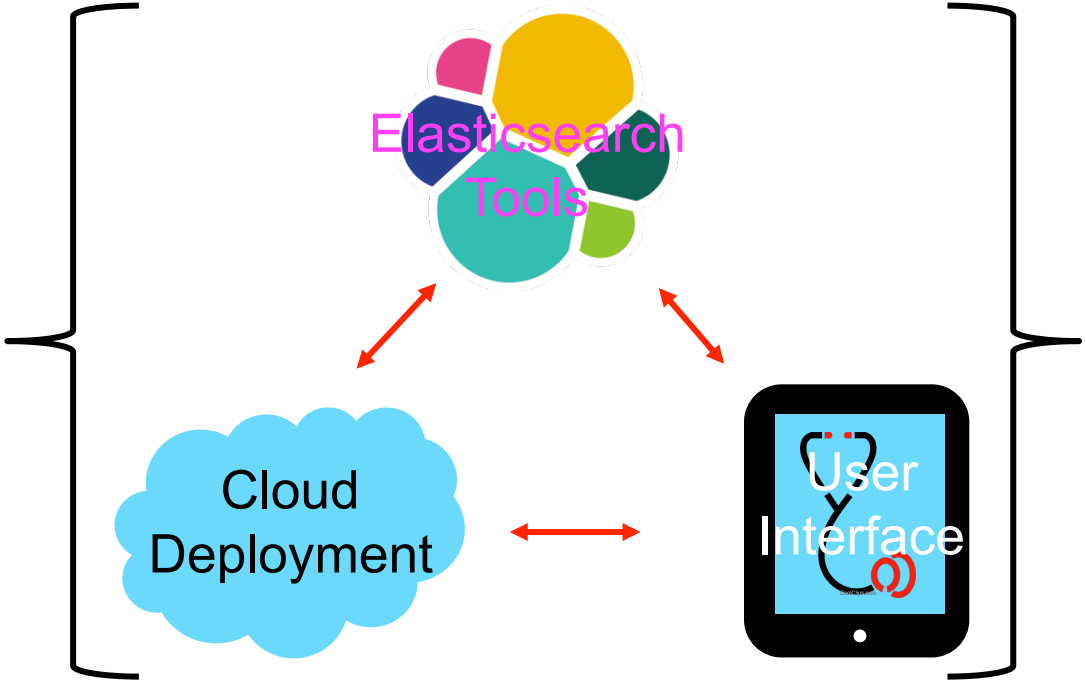
Outline

Introduction to Medicine



Healthcare Analytics

@ Point of Care

Mayo Clinic

- Largest integrated nonprofit medical group practice
- No. 1 on the List of "Best Hospitals in US" [1]
- 4,000 physicians and scientists
- 50,000 allied health staff
- > 1 million unique patients per year

- Leader in electronic medical record (EMR) applications

[1]2014–2015 *U.S. News & World Report*

Enhanced Analytics for Surgical Excellence (EASE)

Making data **meaningful**, **accessible**, and **actionable**

- Objective: Improve surgical outcomes by managing peri-operative care

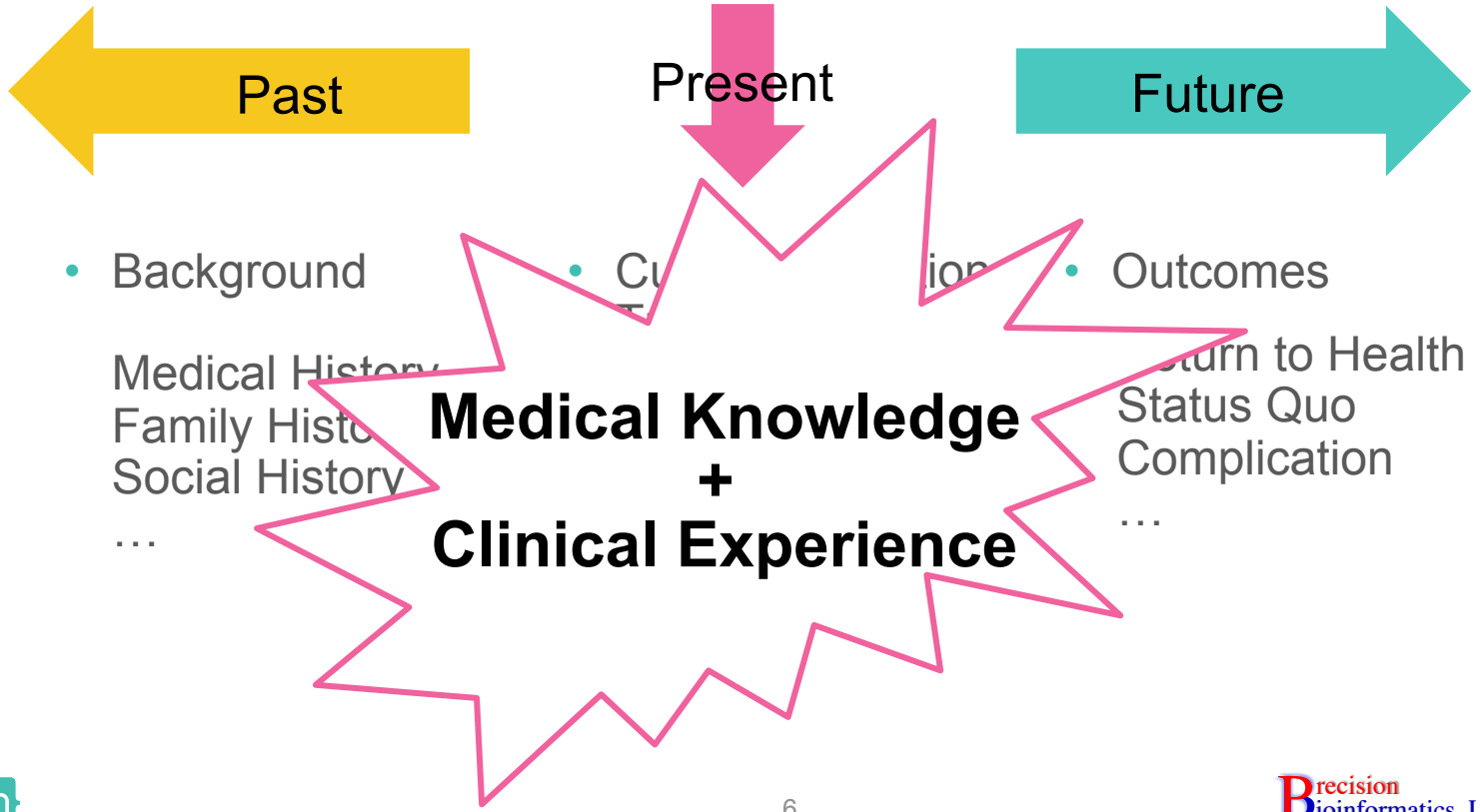
  Clinical : comfort, complication, recovery, …

  Operational : performance, compliance, stress, …

  Financial : length of stay, reoperation, readmission, …

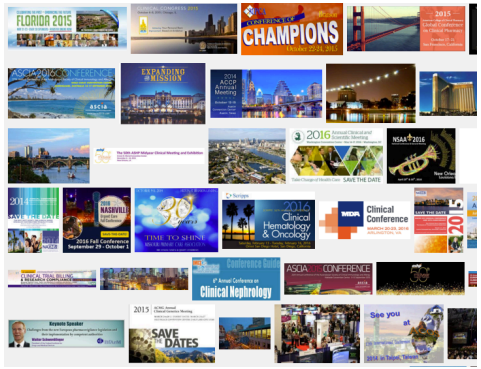
- Sponsor: Dr. David Larson, Chief of Colorectal Surgery, Mayo Clinic

Data at Point-of-Care



Medical Knowledge : Principles of Medicine

Books and Journals



Conferences and Conventions

Training, Fellowships, and CMEs

Clinical Experience : Patient-Specific Patterns

Office Visits

Inpatient Care

Procedures

Gained one patient at a time !

How Can We Expand Clinical Experience

- Improve recall of past patients

  Eliminate subjective bias of recall

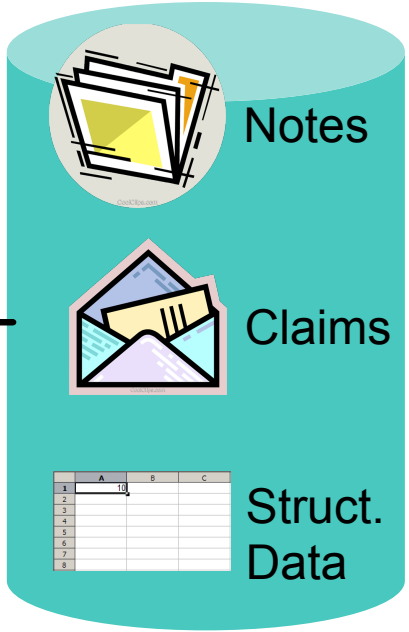
- Overcome the “one-at-a-time” limitation

  Integrate colleagues’ experiences

  And experiences from other institutions

From “Backoffice” Analytics …

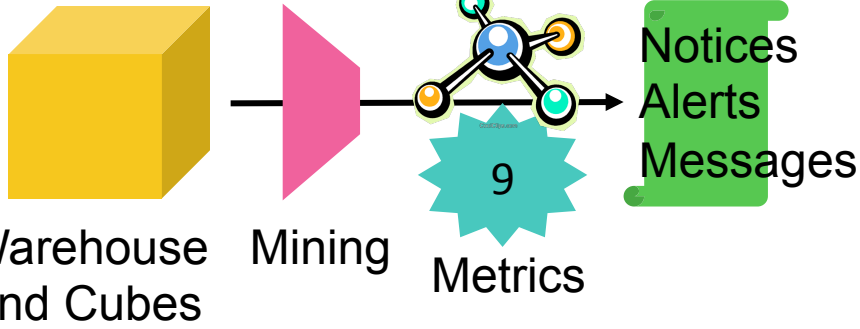
Clinical Activities



EMR

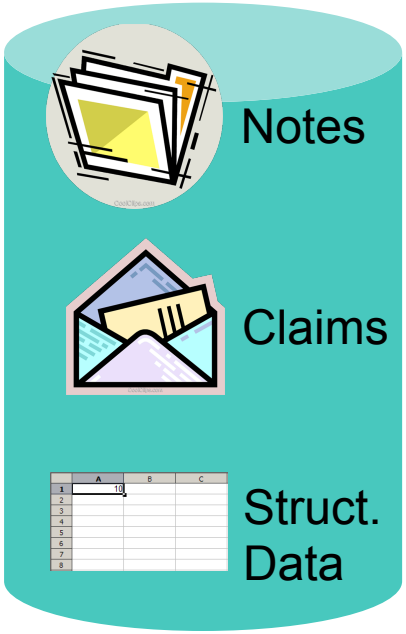
Limitations:

Mining over the “whole” population
Not specific to any given patient



After care has been performed

To Analytics @ Point-of-Care



Clinical Activities

Informed Decisions @ Point of Care

Interactive Visualization

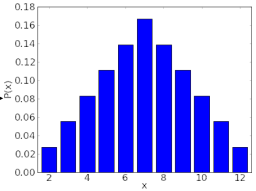
Search Engine

Mining

Models

9

Metrics



Outcomes

Realtime Analytics

Introduction
to
Medicine

Elasticsearch
Tools

Cloud
Deployment

User
Interface

@ Point
of Care

Healthcare Analytics

Platform-as-a-Service

- Patient data is uniform: all patient has the same data types
- Patient data can scale

  practice (clinic): ~1 K – 10 K patients
  department (regional): ~10 K – 1 M patients
  institutional (multi): >1 M patients

- Candidate for a PaaS cloud solution:

  Uniform data in a scalable environment
  Configuration-driven, on-demand deployment

- Straightforward, except for presence of Protected Health Information

Privacy and Security

- Protected Health Information (PHI)

  IDs
  Names
  Addresses
  Phone Numbers

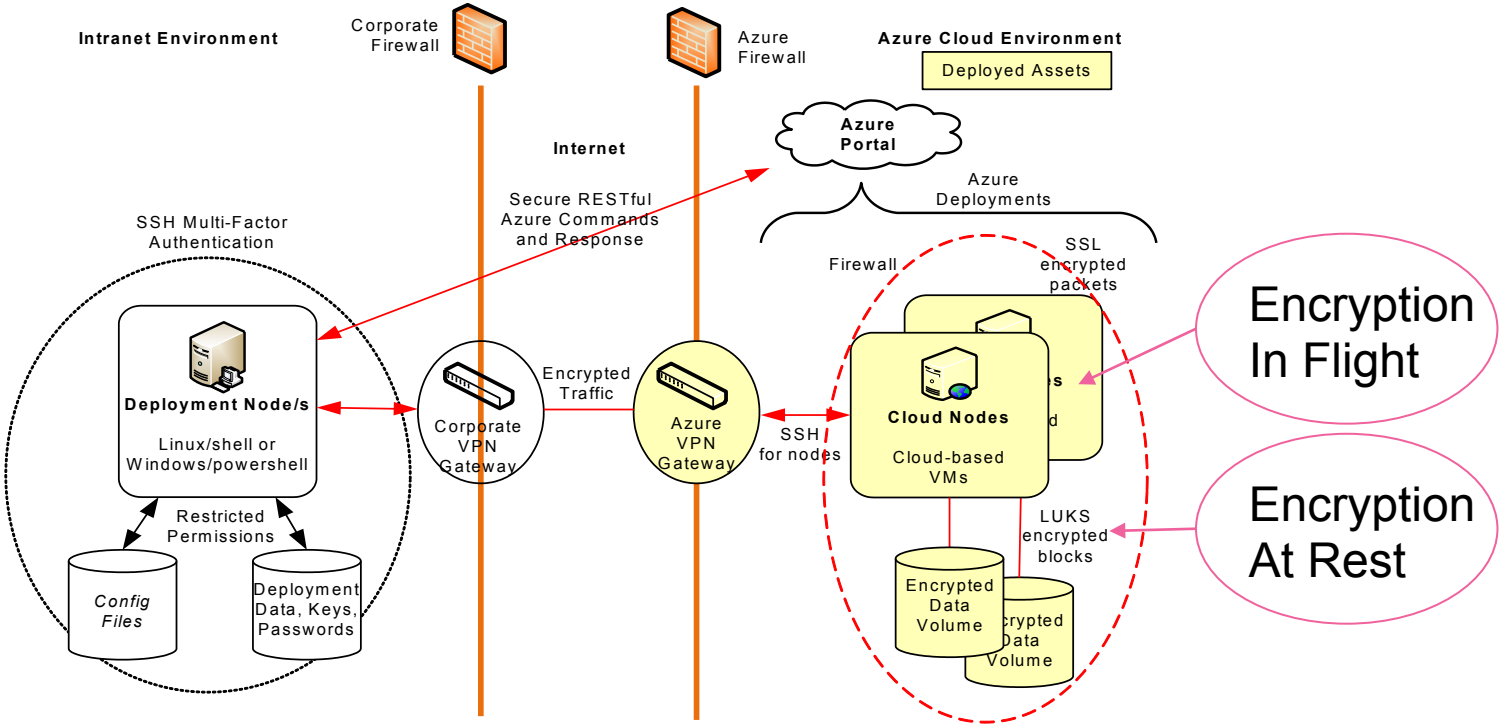
- HIPAA Requirements

  Encryption at rest (files)
  Encryption in flight (network)
  User authentication (who is on)
  Activity logging (who saw what)

- Institutional Requirements

  Passwords, keys, and certificates must be managed locally
  User identity and authentication must be compatible with existing infrastructure

Architecture of Cloud Deployment

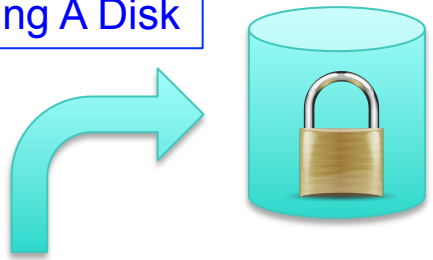


Encryption at Rest

64+ random char Password

Sent at startup

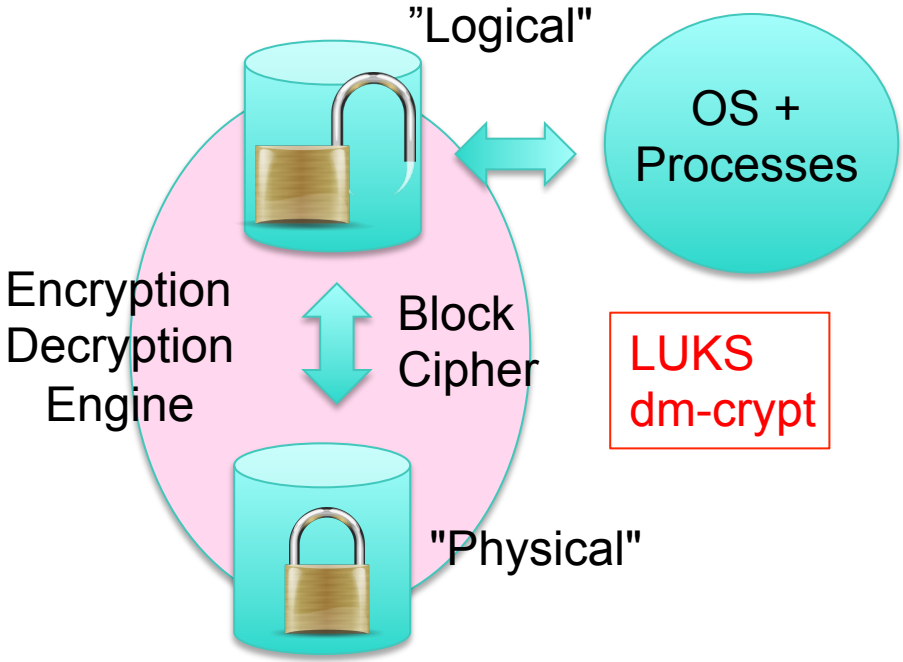
Attaching A Disk



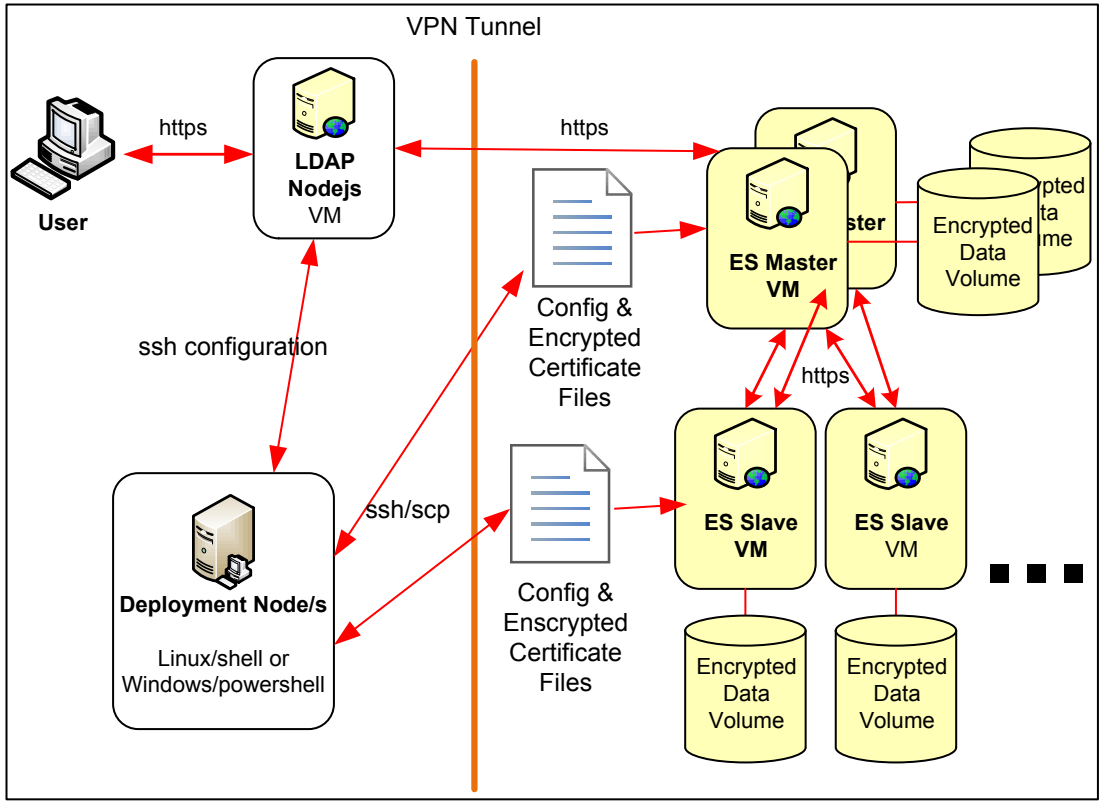
Unattached Disk Volumes

Detaching A Disk

Original file system structure, encrypted blocks

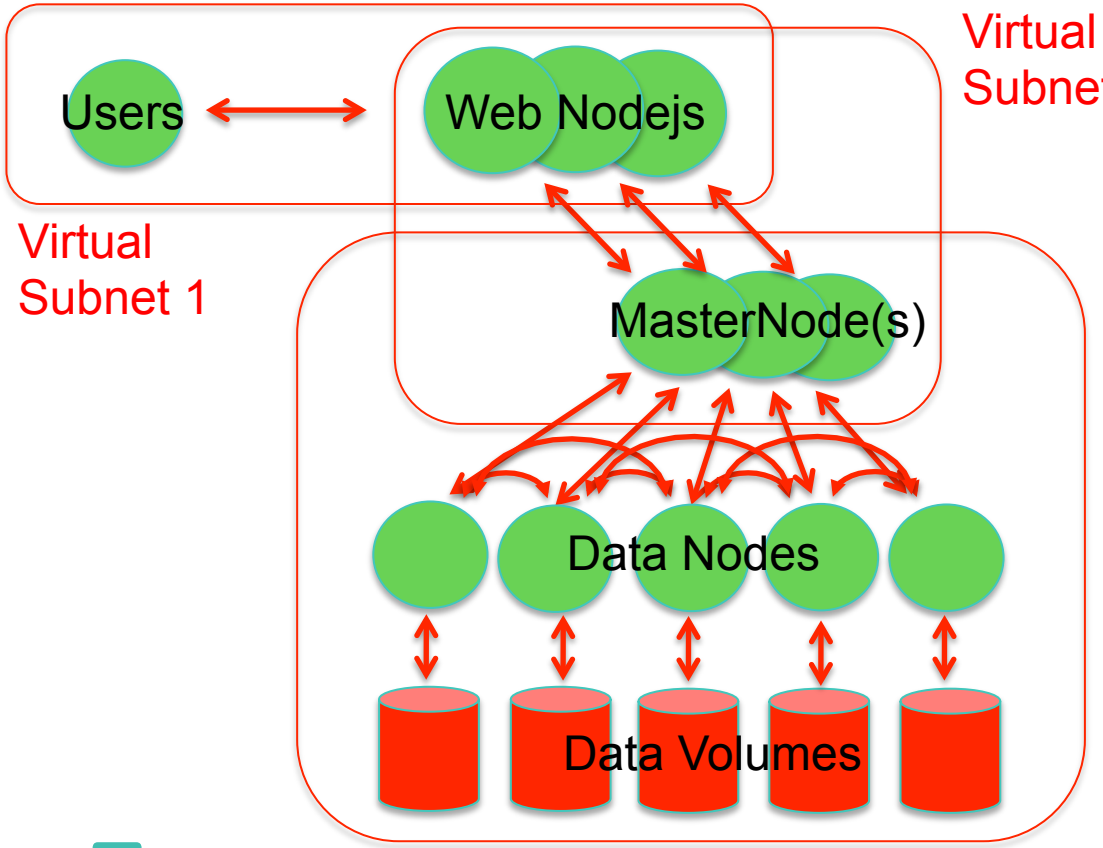


Encryption In Flight



- SHIELD
- But can't leave any passwords in config file
- Use ${prompt.secret}
- Send keystore password during startup through ssh
- Helper process to manage stdin/out and daemonization

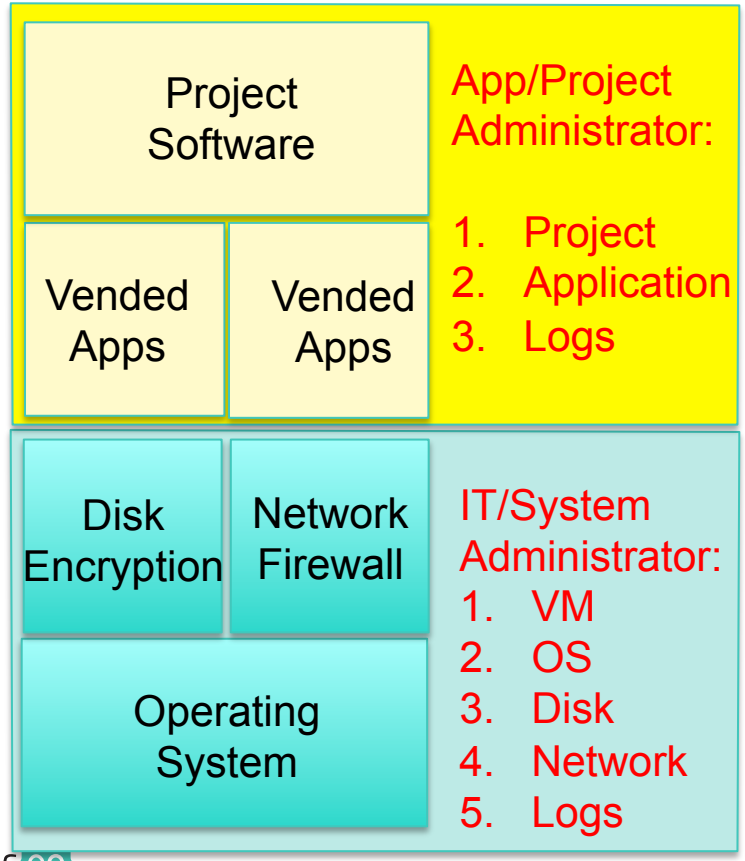
Subnet and Firewalls



- OS-level firewall
- limit open ports
- virtual subnet

- iptables (or equivalent)

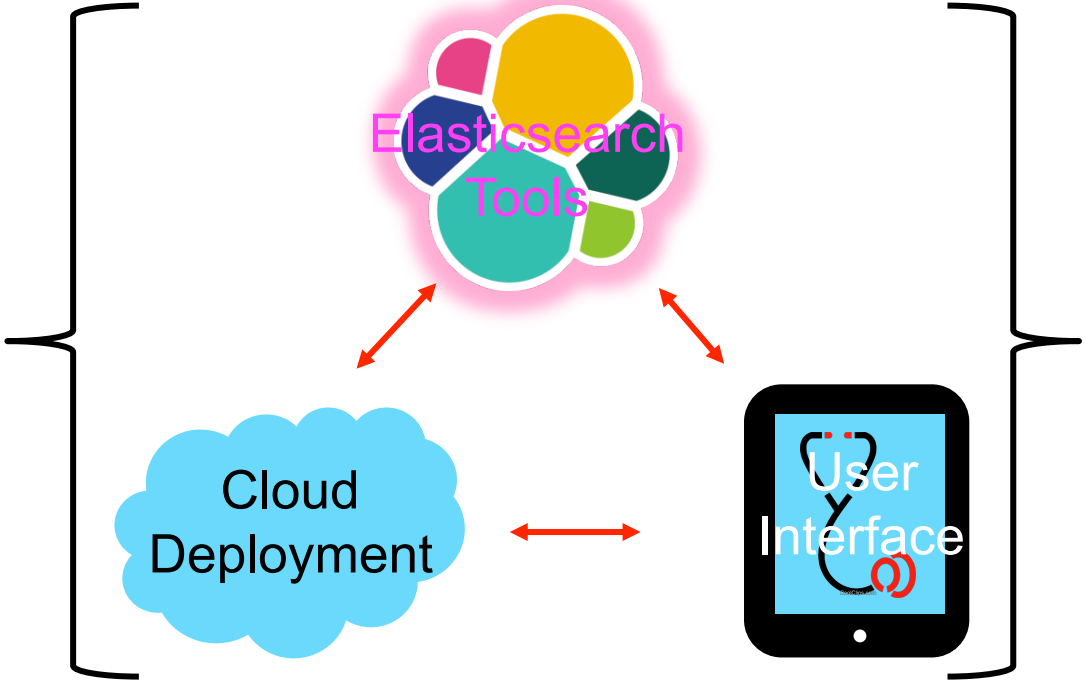
User/Role Authentication



- Separation of IT/System Admin from App/Project Admin roles
- User identity/authentication managed by Intranet LDAP Policies
- LDAP client needs to be in the Intranet (no SHIELD LDAP realm in the cloud)
- User activity via “run as” (untested)

Outline

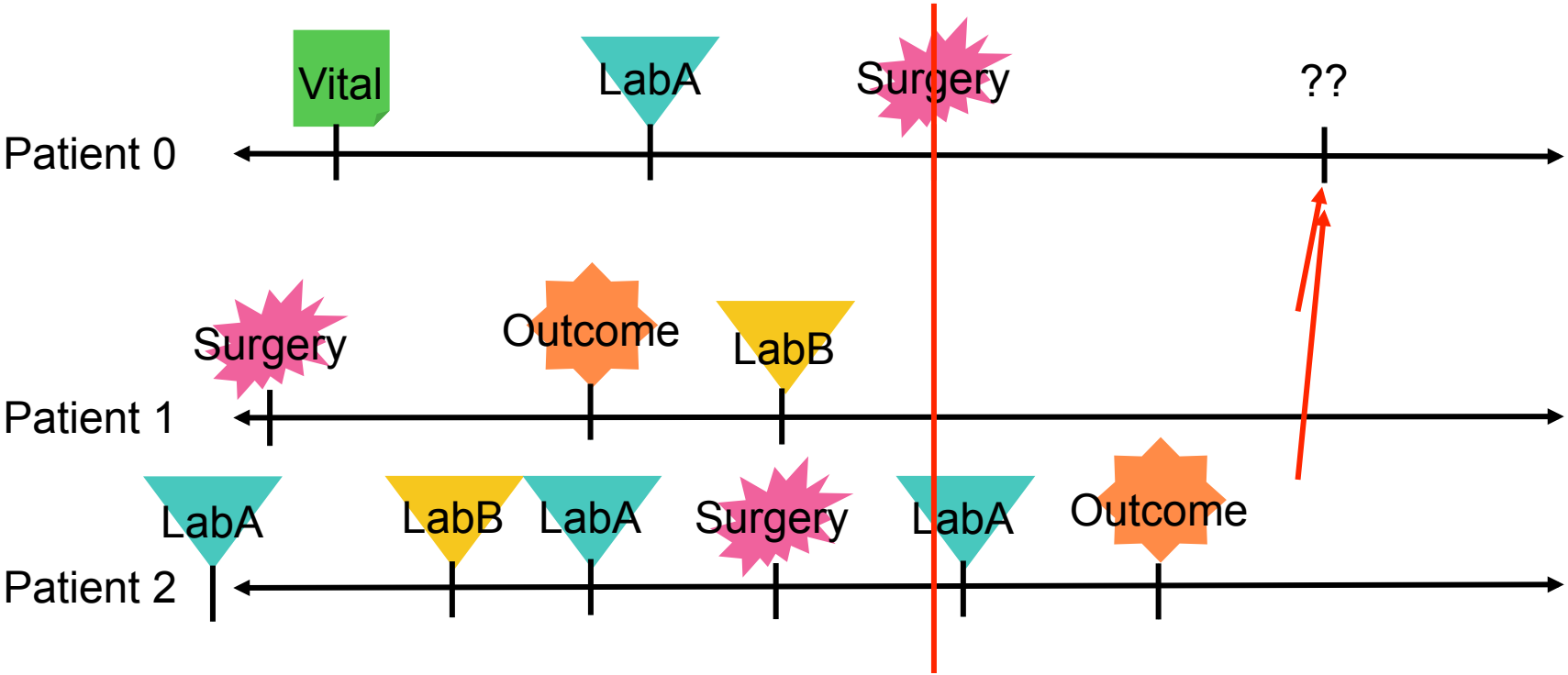
Introduction to Medicine



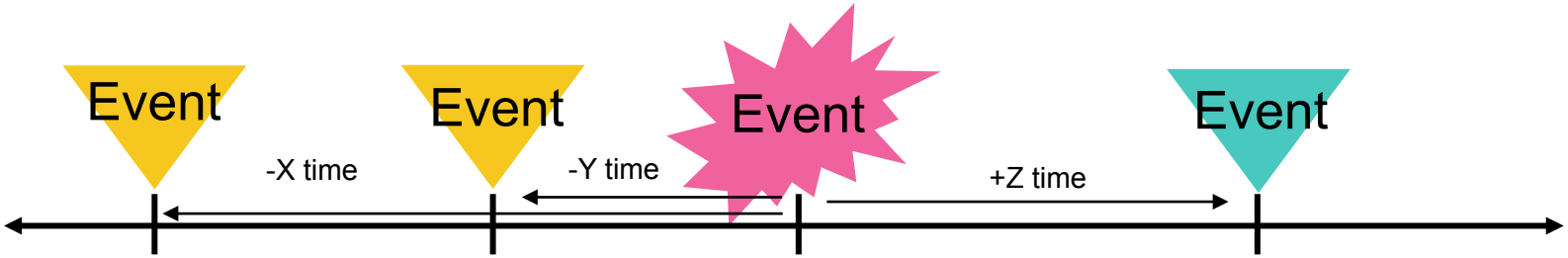
Healthcare Analytics

@ Point of Care

Prediction Using The Past



Reference Events



- Medications
- Lab Values
- Observables
- Flowsheet

Date and Time of

- Symptom Onset
- First Diagnosis
- Admission
- Surgery
- Treatment

- Planning
- Complications
- Resolution
- Discharge

Any event can be set as reference event

Patient-Event Relationships

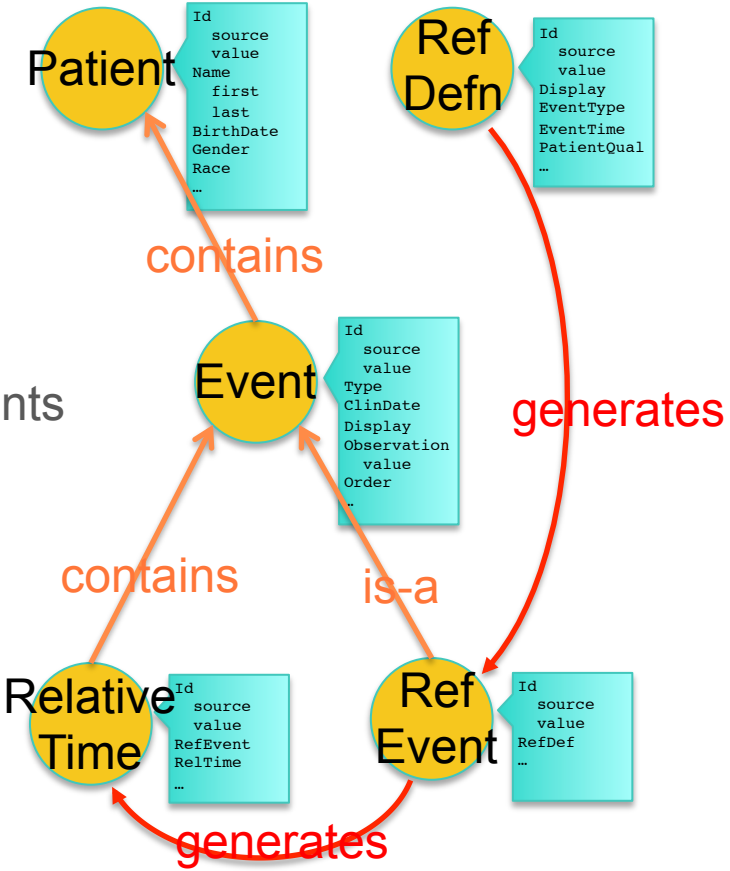
- Medicine is big-data complex ☺

  >10 K Events per patient case
  Volume, Variety, Velocity, Veracity

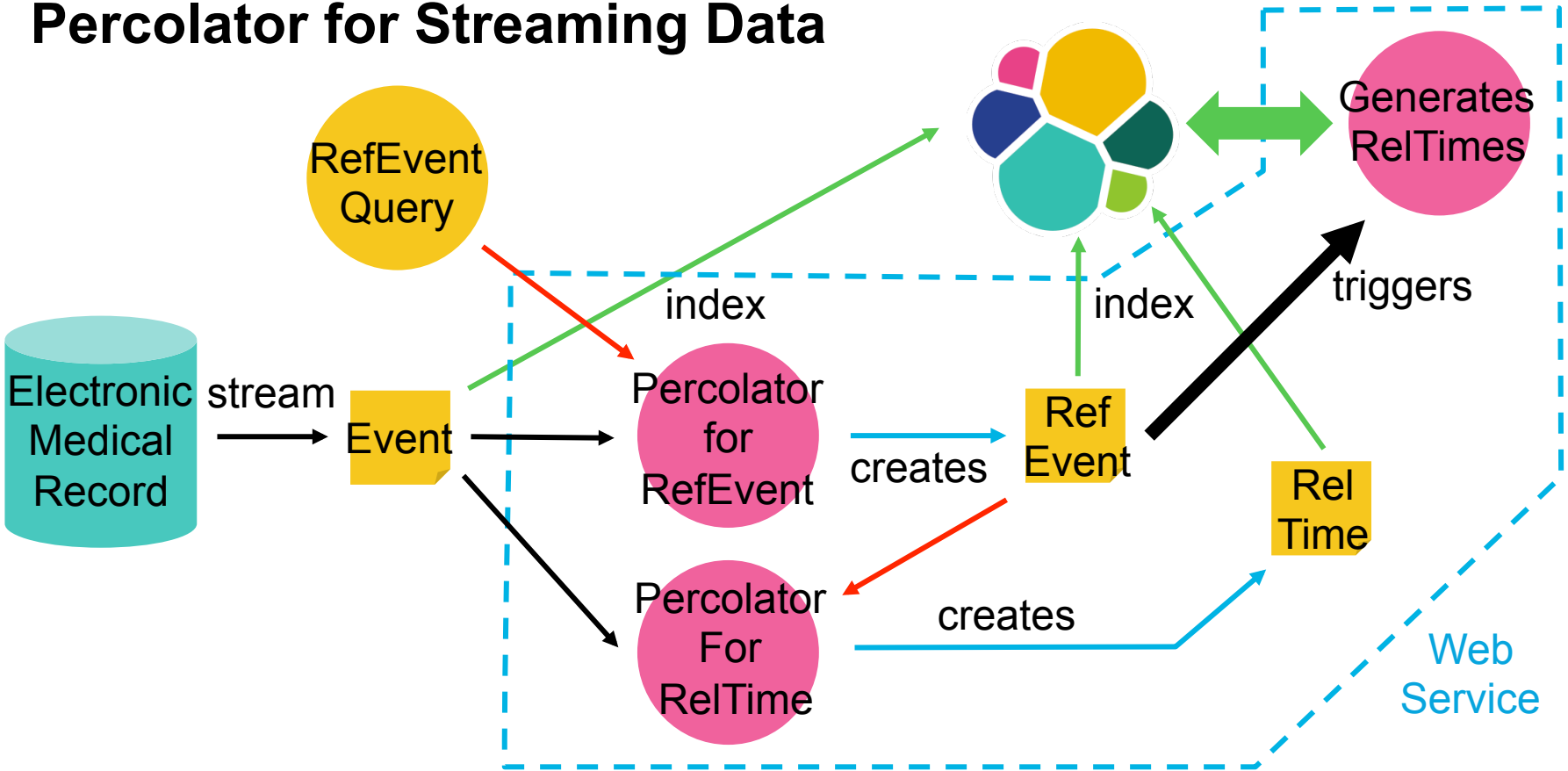
- Constant (and relentless) streaming of Events

  Detect Reference Events
  Generate RelativeTimes

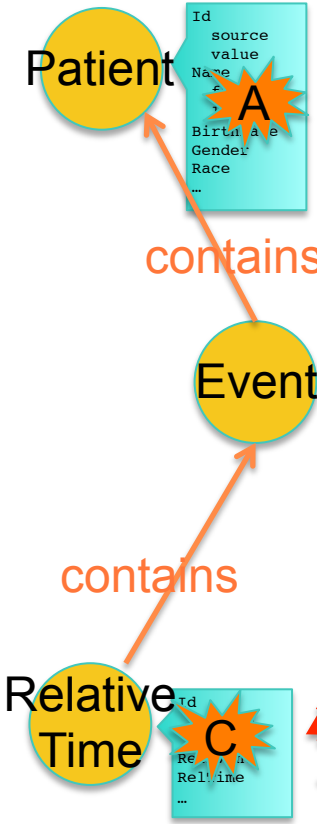
- → Parent-Child relationship



Percolator for Streaming Data



Reduce Query Complexity




```
Elasticsearch Pseudoquery:
{
  query: {
    <clause A>,
    child: { Event : {
      <clause B>,
      child: { RelativeTime : {
        <clause C>
      } }
    } }
  inner : { Event : {
    query : {
      <clause B>,
      child : {
        <clause C>
      }
    inner : { RelativeTime : {
      query : {
        <clause C>
      }
    } }
  } }
}
```

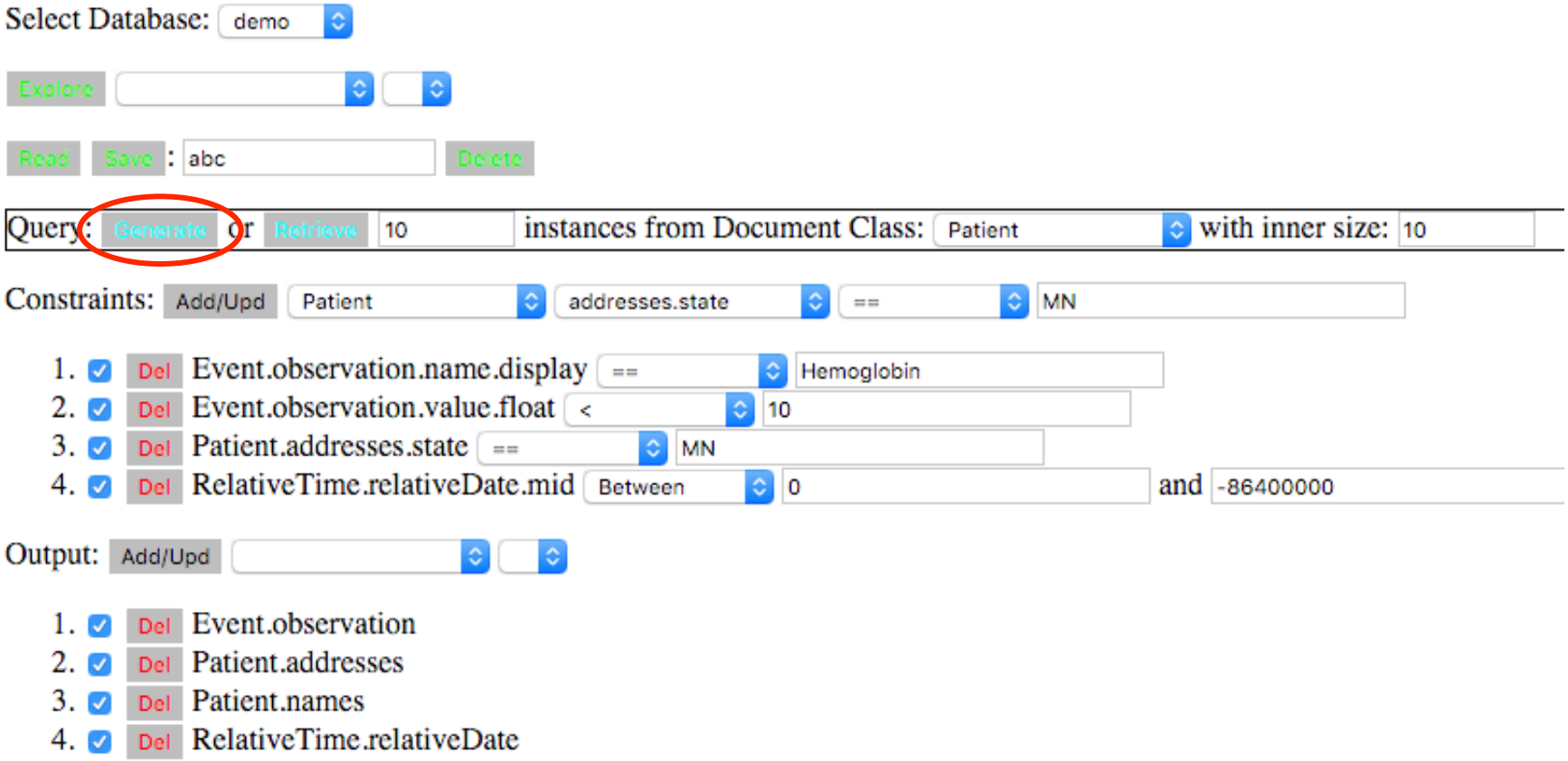
Patients who:

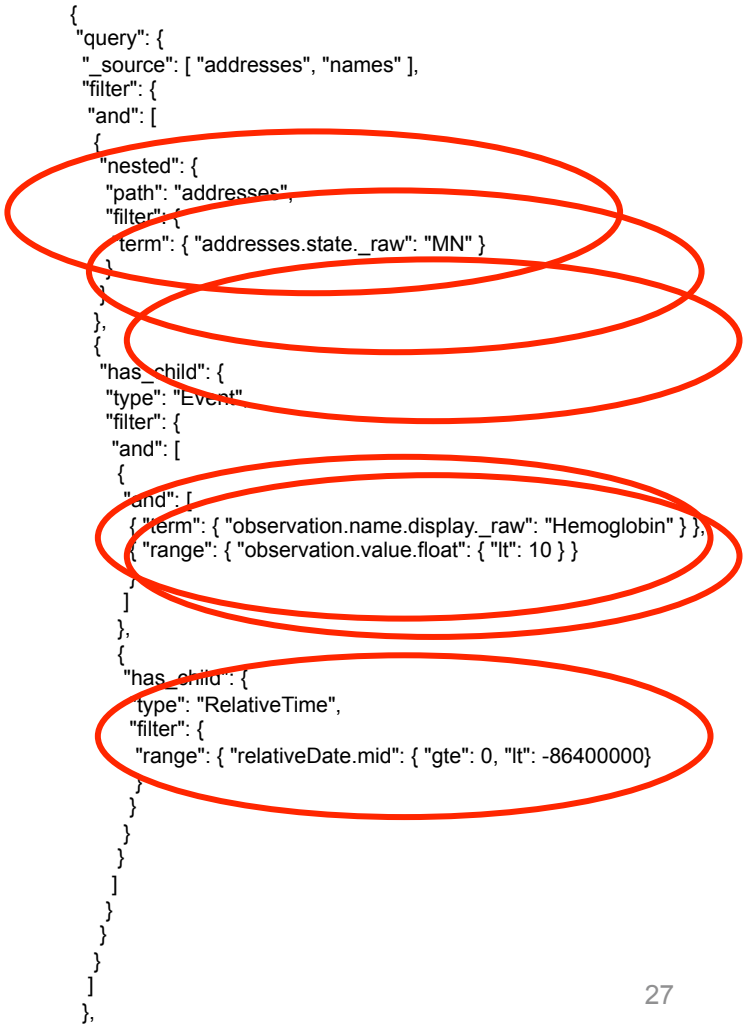
Live in MN

Has hemoglobin lab value <= 10

1 day prior to surgery

And return those values


Select Database: demo
Explore
Read Save : abc Delete
Query: Generate or Retrieve 10 instances from Document Class: Patient with inner size: 10
Constraints: Add/Upd Patient addresses.state == MN
1. Del Event.observation.name.display == Hemoglobin
2. Del Event.observation.value.float < 10
3. Del Patient.addresses.state == MN
4. Del RelativeTime.relativeDate.mid Between 0 and -86400000
Output: Add/Upd
1. Del Event.observation
2. Del Patient.addresses
3. Del Patient.names
4. Del RelativeTime.relativeDate



```
{
 "query": {
  "_source": [ "addresses", "names" ],
  "filter": {
   "and": [
    {
     "nested": {
      "path": "addresses",
      "filter": {
       "term": { "addresses.state._raw": "MN" }
      }
     }
    },
    {
     "has_child": {
      "type": "Event",
      "filter": {
       "and": [
        {
         "and": [
          { "term": { "observation.name.display._raw": "Hemoglobin" } },
          { "range": { "observation.value.float": { "lt": 10 } }
         }
        ]
       },
       {
        "has_child": {
         "type": "RelativeTime",
         "filter": {
          "range": { "relativeDate.mid": { "gte": 0, "lt": -86400000}
         }
        }
       }
      }
     ]
    }
   }
  ]
 },
```

Introduction
to
Medicine

Elasticsearch
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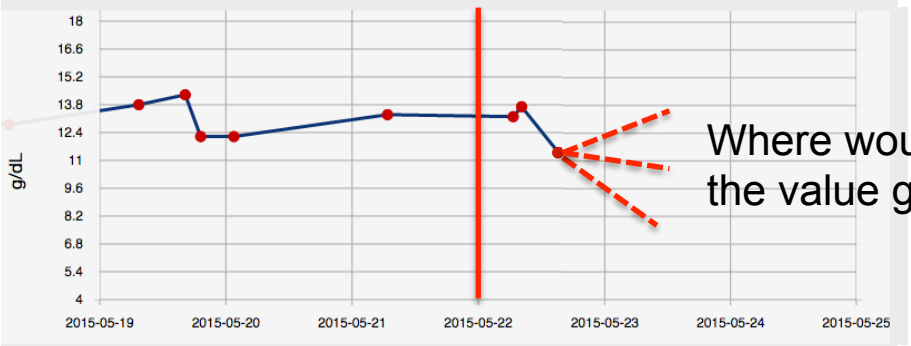
Healthcare Analytics

Patient A had a surgery…

Surgery on May 22, 2015

Hemoglobin



Where would the value go ?

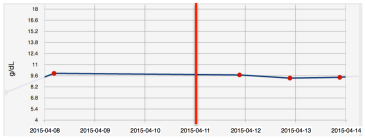
Is patient at risk for bleeding complication (low hemoglobin) ?

Reference Event = surgery

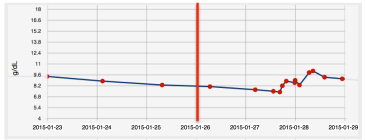
Events of interest = diagnoses and lab values

Find other patients, align, and overlay data lines

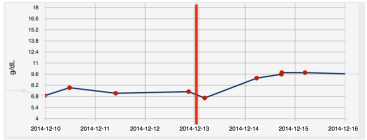
Patient B



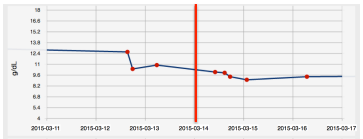
Patient C

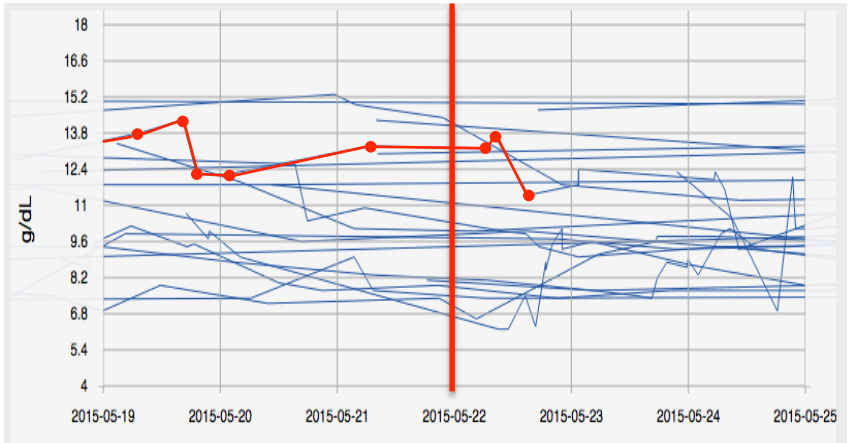


Patient D

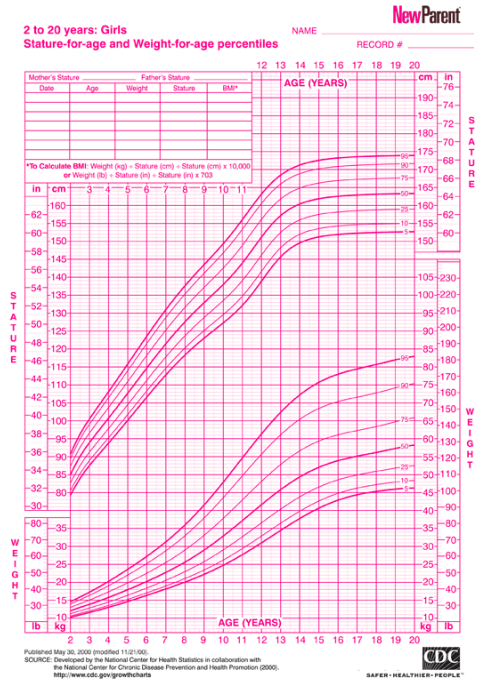


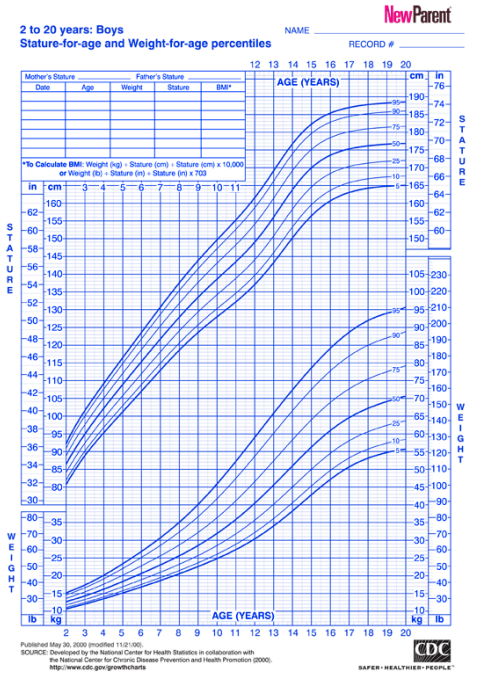
Patient E





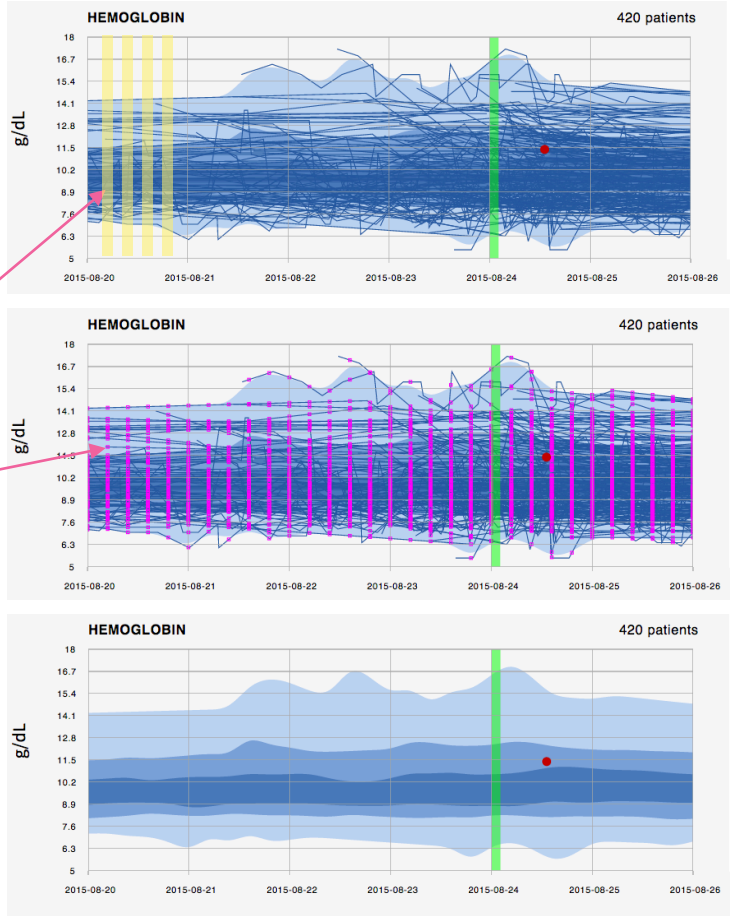
Growth Chart (aka Contour Graphs)





Construct Contours

- Create line segments between adjacent data points
- Divide window into vertical slices (>20)
- For each slice, calculate intersections for each data line
- Determine the 5, 10, 25, … percentile Y intercept-value in each vertical slice
- Connect the percentile (5, 10, 25, …) points into smoothed curves



Realtime User Interaction

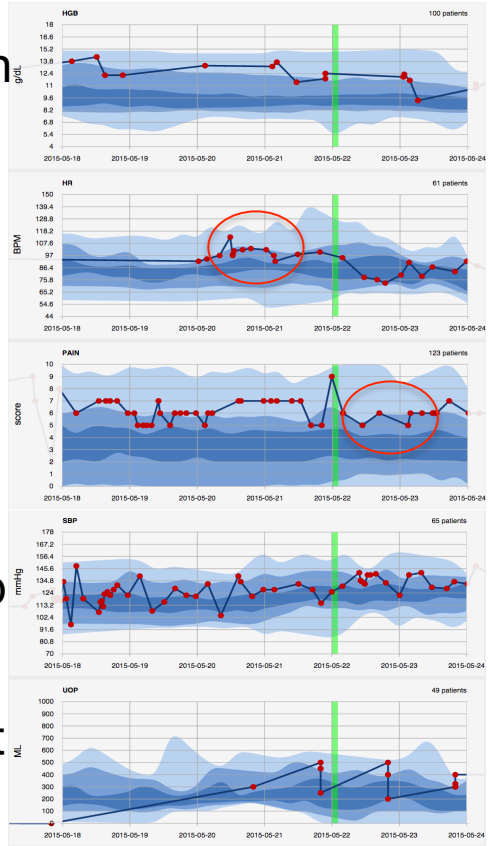
hemoglobin

heart rate

pain score

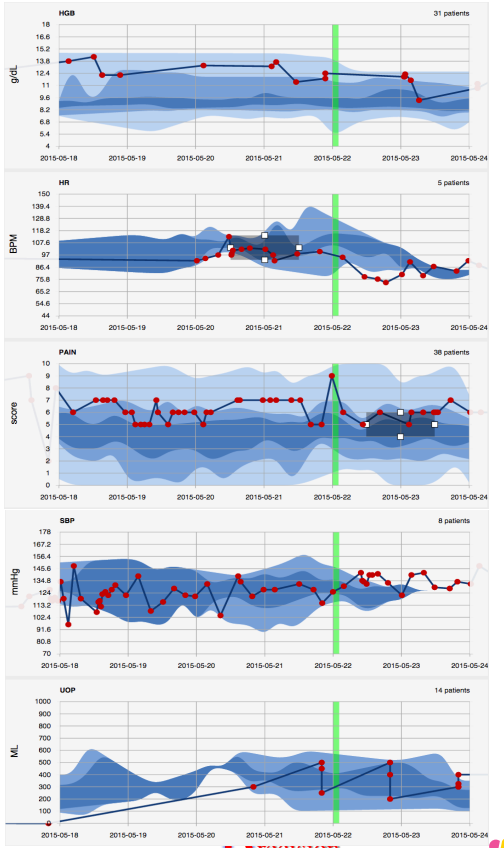
systolic bp

urine output



Add Constraints: Select only patient data lines that pass through bounding box

Cohort (set of patients) then becomes more like our patient



Multiple @ Point-of-Care Applications

- **Clinical Registries**: cohort for diseases, treatments
- **Retrospective Evaluation**: compare treatment, provider outcomes

- **Targeted Outcome**: likelihood of success, necessary actions
- **Educational Tool**: what-if scenarios, e-attending

Summary

- EASE: Making data meaningful, accessible, and actionable
- Representing clinical experience using a graphical metaphor
- Proof-of-concept for delivering analytics at point-of-care

  Secure Cloud Deployment
  Elasticsearch query builder
  Intuitive, real-time user interface

- Evidence-Based, Personalized Medicine

Future Directions

- Text data (contour graph analogy)
- Intuitive analytics, statistical/machine learning
- Optimization of schema and performance
- Usability trials

Acknowledgement

- Simon Yates, Sybaris, Toronto, Ontario
- Jenna Lovely, PharmD, BCPS, Mayo Clinic, Rochester, MN
- David Larson, MD, MBA, Mayo Clinic, Rochester, MN

- Many staff members on the EASE Program
- IT staff of Mayo Clinic

Questions ?

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