Precision Medicine for Health Systems
Enabling the Transformation of Healthcare Systems
November 14th, 2016
Key Messages

1. A variety of data types are needed to enable precision medicine
2. These data types include:
   a. Clinical data
   b. Lab and genomics data
   c. Imaging data
   d. Sensor data
   e. Patient reported data
3. The amount and size of these data sets will require them to be collected in a cloud computing environment
4. Hospital systems need a well thought out, systematic approach to developing the infrastructure to collect and analyze this data
5. If done properly, this comprehensive data set can be used to drive insights and better clinical outcomes and improve drug development through both traditional analytics and machine learning
Enterprises are experiencing a Digital Transformation

Data stored in cloud, simple to query
Machine learning drives deep, actionable insights
Collaborative, cloud based productivity applications
IT changing how it computes.

Data on premise, hard to access, analyze and use
Productivity tools built for individual, local usage
IT focusing on where it computes

2010
Individual Productivity
IT Silos

2020
Collective Intelligence
Distributed Computing
Enterprises are experiencing a Digital Transformation

2010

Individual Productivity

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Data on premise, hard to access, analyze and use

Productivity tools built for individual, local usage

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2020

Collective Intelligence

Distributed Computing

Data stored in cloud, simple to query

Machine learning drives deep, actionable insights

Collaborative, cloud based productivity applications

IT changing how it computes.
The same data and technology can be used for both clinical research and patient care.
Creating the Infrastructure to Support Precision Medicine

Sources
- Epic and Cerner Health Records
- Imaging Systems
- Lab and Genomic Data
- Sensor and PRO data

Settings
- Community Based Care
- Acute Care
- Port-Acute Care
- Ambulatory Surgery Center
- Patients

Data Processing / Google Cloud Based Platform
- Imaging
- Sensors
- Molecular
- Clinical
- Self-Reported Data

Solutions & Apps

Epic and Cerner Health Records
Imaging Systems
Lab and Genomic Data
Sensor and PRO data
Healthcare Capabilities
Standing on the shoulders of the Web

Building on Google's core infrastructure, data analytics, and machine learning.
Platform Vision

**CLINICAL STUDY MANAGEMENT**

**DISEASE MANAGEMENT**

**CUSTOM APPLICATIONS**

**QUALITY & REIMBURSEMENT**

<table>
<thead>
<tr>
<th>API</th>
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shared infrastructure (workflows, frameworks, ...)

**COLLABORATIVE DATA**

**PUBLIC DATA**

**PRIVATE DATA**

Images courtesy of Verily Life Sciences
Clinical Capabilities

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- MOLECULAR
- IMAGING
- SENSORS
- CLINICAL
- SELF-REPORTED DATA

shared infrastructure (workflows, frameworks,...)

Images courtesy of Verily Life Sciences
Mapping Clinical Data

Sources
- Epic and Cerner Health Records
- Imaging Systems
- Lab and Genomic Data
- Sensor and PRO data

Settings
- Community Based Care
- Acute Care
- Port-Acute Care
- Ambulatory Surgery Center

Processing/Warehousing
- Standards Based EHR Adapter
  - DIRECT
  - CCDA
  - Smart
  - FHIR
  - i2b2
- HISP
- Warehouse
- Cleansing/Translating

Registry
- Registry 1
- Registry 2
- Registry 3
- Registry 4
- Registry 5
Getting Data Mapping Right - Core Suite Tools

**End User eMeasure Specification Editing Tool**
Allows analysts to leverage the eMeasures knowledge base to edit and add. Provides simple way to define complex rules for calculating measures using the built-in rule editor. Drives presentation in CoreIQ.

**Dashboard**
Offers Intelligence Query capabilities for end users to enable quality delivery and financial management for hospitals and physicians. Provides measure-centric content with a population-focused context.

**eMeasure Data Tool and Knowledge Base**
Guides EHR implementation and remediation to get the right data, standards, content, and workflow. Supports customized measures development.

**Value Set Management**
Includes lists of specific values (terms and their codes) derived from single or multiple standard vocabularies (SNOMED, ICD-10, ICD-9, RxNorm, LOINC, etc.) used to define clinical concepts (e.g. patients with diabetes, clinical visit, reportable diseases) in eMeasures and required for population analysis. Sourced from regulatory and standards organizations.

**Smart, Skinny Analytics Engine**
Performs in-situ data derivation and measure calculations. Employs the Measure Reference Model metadata from CoreGPS to derive intermediate and complex Information from sourced data. Stores these derived elements and logical assertions alongside the detailed source evidence to enable detailed drill-downs, analysis, and reporting. Integrates measure results back into the Analytics Data Home to enable multi-level analysis and advanced ad-hoc reporting.
## Getting Data Mapping Right - Risk Assessment Process

<table>
<thead>
<tr>
<th>Source Content from CMS</th>
<th>Detailed Content from Risk Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Risk Priority Code</td>
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<tr>
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### Functionality/Certification

- **Workflow**
- **Content**
- **Adoption**
- **Reporting**
Provider analytics

Your hospital had a 10.1% longer length-of-stay for Knee Joint Replacement (127 bed-days which costs $549,004.20). This change may be driven by severity 2 cases, which are higher by 10.3%. The longer stays in severity 2 could account for 49.5% (63 bed-days) of the total increase.
Genomics Capabilities

<table>
<thead>
<tr>
<th>Genomics Capabilities</th>
<th>Clinical Study Management</th>
<th>Disease Management</th>
<th>Custom Applications</th>
<th>Quality &amp; Reimbursement</th>
</tr>
</thead>
</table>

- **API**
  - Molecular
  - Imaging
  - Sensors
  - Clinical
  - Self-reported data

- **Analysis Tools**

  - Shared infrastructure (workflows, frameworks, ...)

- **Data**
  - Collaborative data
  - Public data
  - Private data

Images courtesy of Verily Life Sciences
Genomics workflow
PrecisionFDA
Truth Challenge

President Obama’s Precision Medicine Initiative envisions a day when an individual’s medical care will be tailored in part based on their unique characteristics and genetic make-up.

The goal of the FDA’s second precisionFDA challenge, similarly to the first challenge, is to continue engaging the genomics community in advancing the quality standards in order to achieve more accurate and consistent results in the context of genetic tests (related to whole human genome sequencing), advancing the goal of better personalized care.

PrecisionFDA invites all innovators to take the challenge and assess their (or their favorite!) software on the supplied human datasets. Participation is voluntary, but instrumental in helping the community prepare for the coming genomic data revolution.
PrecisionFDA Truth Challenge
April 26, 2016 through May 26, 2016

INPUT
HG001 FASTQs
HG002 FASTQs

YOUR PIPELINE

YOUR OUTPUT
HG001 VCF
HG002 VCF

REFERENCE
HG001 Reference VCF
HG002 Reference VCF

COMPARISON
HG001 Comparison Results
HG002 Comparison Results

CHALLENGE LAUNCH: APRIL 26th, 2016
Input files are made available

APRIL 26th - MAY 26th, 2016
Participants use the same pipeline on both input samples

DEADLINE: MAY 26th, 2016
HG002 Reference VCF revealed

Participants run the HG001 comparison and submit it along with their HG001 and HG002 output VCFs

PrecisionFDA runs the HG002 comparison after the challenge deadline
## PrecisionFDA Truth Challenge

### SNP Performance

**Awarded to**

**Verily Life Sciences**

Ryan Poplin  
Mark DePristo  
Verily Life Sciences Team

<table>
<thead>
<tr>
<th>ENTRY</th>
<th>TYPE</th>
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<th>SUBSET</th>
<th>GENOTYPE</th>
<th>F-SCORE</th>
<th>RECALL</th>
<th>PRECISION</th>
<th>FRAC_NA</th>
<th>TRUTH TP</th>
<th>TRUTH FN</th>
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Imaging Capabilities

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shared infrastructure (workflows, frameworks,...)

Images courtesy of Verily Life Sciences
Diabetic Retinopathy
Other research possibilities...

**RETINA**

**EYE DISEASES**
- Glaucoma
- Age-related macular degeneration

**SYSTEMIC DISEASES**
- Stroke & heart attack risk
- Diabetic nephropathy, neuropathy
- Vascular dementia, Alzheimer’s
- Mortality? Hospitalizations?

**OTHER IMAGING**

**SKIN CONDITIONS**
- Moles
- Skin cancer
- Infections
- Acne/rosacea
- Dermatitis
- Hair/nail

**EAR, NOSE, THROAT**
- Ear infections
- Sore throat
Sensor Data Capabilities

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shared infrastructure (workflows, frameworks,...)

Images courtesy of Verily Life Sciences
send the right data to the right algorithms at the right times
Pipeline Example: pulse data computation

Raw Firehose → ppg data

Collect 1 hr → acc data

Collect 1 hr → activity

Idle pulse → Active pulse

Pulse estimate → 15 minute Summaries

Pulse Recovery Regions

Pulse Recovery Model

<table>
<thead>
<tr>
<th>Max (mins)</th>
<th>Hard (mins)</th>
<th>Moderate (mins)</th>
</tr>
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<tbody>
<tr>
<td>Yes</td>
<td>81</td>
<td>5</td>
</tr>
<tr>
<td>30-44 yr males</td>
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</tr>
<tr>
<td>24-29 yrs</td>
<td>81</td>
<td>91</td>
</tr>
<tr>
<td>Study Average</td>
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<td>91</td>
</tr>
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</table>
Pipeline Example: sleep quantity and quality

Raw Firehose (~18 hours)

Activity Classification (~18 hrs)

Sleep Onset/Offset Detection

HR Estimation

Extract Nighttime PPG Using Sleep Onset/Offset Detections

Sleep Onset/Offset Detection Model (Red)

REM

NREM

Model (Red)

Conf (Dash)

Heart Rate Variability

Sleep Stager

Peak-To-Peak Variation

PPG Measurement
Solutions: Baseline Study

API
- Molecular
- Imaging
- Sensors
- Clinical
- Self-reported data

Analysis Tools

Shared infrastructure (workflows, frameworks,...)

Images courtesy of Verily Life Sciences
“Google has embarked on what may be its most ambitious and difficult science project ever: a quest inside the human body.”

Wall Street Journal | July 2014
Broad and Deep Molecular, Device, and Clinical Phenotyping Data for Each Participant

Clinical Data

Device Data

Imaging Data

-Omics Data

Immunoprofiling Data

PPG
Sound
Accel

-20,000 genes

-Week 0

-Week 16

-Week 0

-Week 16

- Monocytes
- B cells
- CD4 T cells
- CD8 T cells
- other
Ingestion, preprocessing, QC: Import data at LIMS-level. Automatically survey data quality and highlight areas of concern. Determine pre-analytical, analytical, and biological variability.

Clustering: unbiased or hypothesis-weighted clustering of multi-omics data to reveal unique patterns.

Regression: supervised or semi-supervised methods that import known biological information.

Longitudinal: analysis and sequence prediction in longitudinal data.

eQTL/mQTL: integrative analysis combining multiple genetic data types.

GRS: genomic predisposition; advanced modeling across multiple population data.

Advanced machine learning: for integrative pathway discovery & analysis, data annotation, quality control, and phenotype-*omics associations.
Solution: Quality Improvement / MACRA

CLINICAL STUDY MANAGEMENT

DISEASE MANAGEMENT

CUSTOM APPLICATIONS

QUALITY & REIMBURSEMENT

API

Analysis Tools

MOLECULAR

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shared infrastructure (workflows, frameworks,...)

COLLABORATIVE DATA

PUBLIC DATA

PRIVATE DATA

Images courtesy of Verily Life Sciences
The MACRA Quality Payment Program Consolidates key aspects of three existing physician-based programs:

- Merit-based Incentive Payment System (MIPS)
- Advanced Alternative Payment Models (Advanced APM)
- Qualifying APM Participant

Separate Requirements & Separate Submission

- Medicare EP MU
- Medicaid EP MU
- PQRS
- Value-based Modifier

Eligible Clinicians

Composite Performance Score

Qualifying APM Participant

Risk-based Payment arrangements
### Data Submission Mechanisms for Groups

#### Quality
- Qualified Clinical Data Registry (QCDR)
- Qualified registry
- EHR
- CMS Web Interface (groups of 25 or more)
- CMS-approved survey vendor for CAHPS for MIPS (must be reported in conjunction with another data submission mechanism)

#### Resource Use
- Administrative claims (no submission required)

#### CPIA
- Attestation
- QCDR
- Qualified registry
- EHR
- CMS Web Interface (groups of 25 or more)
- Administrative claims (if technically feasible, no submission required)

#### Advancing Care Information
- Attestation
- QCDR
- Qualified registry
- EHR
- CMS Web Interface (groups of 25 or more)

**Source:** MIPS and APMs Incentive Under the PFS Proposed Rule – page 83
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Solutions & Apps
- CoreGPS
- Google Cloud Platform
- MACRA
- Population Health
- RESEARCH
- TCGA