Challenges and Opportunities in Molecular Diagnostics as Key Components of Molecular Medicine

Dr. George Poste
Chief Scientist, Complex Adaptive Systems Initiative and Del E. Webb Chair in Health Innovation
Arizona State University
george.poste@asu.edu
www.casi.asu.edu
Declared Interests:

- Board of Directors: Monsanto, Exelixis, Caris Life Sciences
- Scientific Advisory Board: Burrill and Co., Synthetic Genomics, Anacor
- IOM Forum on Global Infectious Diseases
- USG Activities: DoD, DHS

Slides available @ www.casi.asu.edu
Sustaining Healthcare Innovation in an Era of Constraint

Biomarkers and Diagnostic Technologies as Major Value Drivers in Improving Diagnostic Accuracy, Treatment Selection and Controlling Costs

The Challenge of Translation of Discovery Advances to Tangible Benefits for Patients and Society
Medical Progress: From Superstitions to Symptoms to Signatures
ID of Causal Relationships Between Network Perturbations and Disease

Patient-Specific Signals and Signatures of Disease or Predisposition to Disease
Mapping Causal Perturbations in Molecular Pathways and Networks in Disease: Defining a New Taxonomy for Disease

Disease Profiling to Identify Subtypes (+ or - Rx Target)

ID Molecular Targets for MDx and/or Rx Action
Mapping the Molecular Signatures of Disease, Disease Subtyping and Targeted Therapy: The Right Rx for the Right Disease (Subtype)

Her-2+ (Herceptin)  
EML4-ALK (Xalkori)  
KRAS (Erbitux) (Vectibix)  
BRAF-V600 (Yervoy) (Zelboraf)
Disease Subtyping and Targeted Therapy: The Right Rx for the Right Disease Subtype

- improved clinical outcomes
- cost-effectiveness in eliminating futile Rx
- reducing high failure rate of investigational drugs in clinical trials by testing only on relevant patients
  - faster and cheaper trials
  - greater regulatory clarity
  - premium pricing for guaranteed outcomes (P4P)
Critical Challenges for Biomedical R&D

- Acceleration of discovery phase knowledge without parallel gains in successful clinical translation and commercial ROI
- Unacceptable high rates of failure of candidate Rx in clinical trials
- Major knowledge gaps for rational discovery strategies to provide solutions for late onset chronic diseases
  - Cancer, diabesity and neurodegeneration
Molecular Diagnostics (MDx)
Frost and Sullivan 2011 and Dark Report 16 March 2012

- fastest growing segment of clinical pathology laboratory testing market
  - $4.1 billion vs IVD $48 billion (2010)
  - projected 11% CGR vs <5% IVD
- 600 hospitals and 200 independent labs using MDx assays
- 9 global companies control 75% market share
- 60% MDx revenues from infectious diseases testing
  - HIV, HPV, HBV, HCV, CT/NG
  - C.difficile and MRSA
Evaluation and Validation of Biomarker-Based Diagnostic Tests

- proof of concept (poc) and clinical validation
  - do changes in biomarker expression correlate with disease risk and/or disease development and/or stage of disease and/or predict treatment response?
- analytical validation
  - robust, reproducible assay method
- clinical utility and ‘fit for purpose’
  - validation and regulatory approval for “intended use” setting(s)
  - compatibility with clinical practice/guidelines
- improved outcomes
  - demonstration that biomarker-driven changes in treatment decisions yield clinical/economic benefits
Translation of the Major Potential of Molecular Medicine into Routine Clinical Practice

The Poor Productivity of Biomarker R&D is a Legacy of Failure to Address Disease Complexity and the Need for Multidisciplinary Expertise and Rigorous Standards

The Complexity of Discovery and Validation of Biomarkers for Clinical Use is Comparable to (Bio)Pharmaceutical R&D

Success Demands a Systems-Based Approach
Identification and Validation of Disease-Associated Biomarkers: Obligate Need for a Systems-Based Approaches

Biospecimens and Molecular Pathway Analysis

Biomarker Validation and Multiplex Assays

Instrumentation and Informatics

Clinical Impact and Patient Monitoring
The Systems-Based Approach to Biomarker Validation

- Subject Selection
- Specimens
- Study Design and Statistical Analyses

Standardization
- Preanalytical
- Analytical
- Data
Rigorous Selection of Specimen Donors and Specimen Collection

- poorly standardized tissues and erratic availability
- challenge of obtaining fresh tissue
- uncertain value of legacy tissue blocks

primacy of standardized clinical phenotyping and annotated health records and outcomes for biospecimen collection
Access to High Quality Biospecimens, Biobanks and DNA Repositories: A Major Obstacle for Biomarker Discovery
Access to Quality Biospecimens for Medical Research: A Critical ‘Choke Point’ in Biomedical Research

Ease of Acquiring the Quality of Biospecimens

- Difficult/Very difficult: 48%
- Somewhat difficult: 32%
- Somewhat easy: 13%
- Very easy/Easy: 8%

Question Their Data Because of the Quality of Biospecimens

- Never/Rarely: 40%
- Sometimes: 40%
- Often/Always: 20%
- Never/Rarely: 19%

Limit Research Scope of Work Due to the Shortage of Quality Biospecimens

- Sometimes: 36%
- Often/Always: 45%

Time Between Ligation Of Main Artery And Tumor Resection (Intrasurgical Ischemia) Affects Gene Expression In Colon Cancer (NCI-Indivumed study)

Intrasurgical Ischemia

PCA mapping: grouping of warm ischemia time points

Indivumed-NCI Study: Courtesy of Dr. C. C. Compton
Influence of Blood Collection Method on Detection of miRNAs

Comparison of Effect Sizes Associated With Biomarkers Reported in Highly Cited Individual Articles and in Subsequent Meta-analyses

John P. A. Ioannidis, MD, DSc
Orestis A. Panagiotou, MD

Many biomarkers are continuously proposed as potential determinants of disease risk, prognosis, or response to treatment. The plethora of statistically significant associations increases expectations for improvements in risk appraisal. However, many markers get evaluated only in 1 or a few studies.

Context: Many biomarkers are proposed in highly cited studies as determinants of disease risk, prognosis, or response to treatment, but few eventually transform clinical practice.

Objective: To examine whether the magnitude of the effect sizes of biomarkers proposed in highly cited studies is accurate or overestimated.

Data Sources: We searched ISI Web of Science and MEDLINE until December 2010.

Study Selection: We included biomarker studies that had a relative risk presented in their abstract. Eligible articles were those that had received more than 400 citations in the ISI Web of Science and that had been published in any of 24 highly cited biomedical journals. We also searched MEDLINE for subsequent meta-analyses on the same associations (same biomarker and same outcome).

Reliability of ‘new drug target’ claims called into question

Bayer halts nearly two-thirds of its target-validation projects because in-house experimental findings fail to match up with published literature claims, finds a first-of-a-kind analysis on data irreproducibility.
“The technological capacity exists to produce low-quality data from low-quality analytes with unprecedented efficacy.”

“We now have the ability to get the wrong answers with unprecedented speed.”

Dr. Carolyn C. Compton
Director, Office of Biorepositories and Biospecimen Research
National Institutes of Health
‘Institute of Medicine Workshop, July 2010’
Large Scale Profiling of Cancer Patients to Identify Cohorts Expressing Rx Target(s) for Phase II Trials

<table>
<thead>
<tr>
<th>Target</th>
<th># Patients Screened</th>
<th># Eligible Patients</th>
<th># Centers</th>
<th># Countries</th>
</tr>
</thead>
<tbody>
<tr>
<td>EML4 ALK⁺: lung cancer*</td>
<td>1500</td>
<td>82</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>HER2⁺: gastric cancer**</td>
<td>3803</td>
<td>549</td>
<td>122</td>
<td>24</td>
</tr>
</tbody>
</table>

* E.L. Kwak et al. (2010) NEJM 363, 1693  
** Y. Bang et al. (2010) Lancet 376, 687
The Importance of Standardized Methods and Data Tracking Systems for Biobanks

- NCI Office of Biorepositories and Biospecimen
- OECD Research: National Biospecimen Network
- PHOEBE (EU): Promoting Harmonization of Epidemiological Biobanks in Europe
- BBMRI: Biobanking and Biomolecular Resources Research Infrastructure
- P3G: Public Population Project in Genomics
- UK Biobank
**Analytical Platforms for the Elucidation of the Design and Regulation of Complex Biological Networks**

### Massively Parallel Biosignature Profiling

<table>
<thead>
<tr>
<th>genomics</th>
<th>proteomics</th>
<th>immunosignatures</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>[Image 0x-6 to 721x188]</td>
<td></td>
</tr>
</tbody>
</table>

- Automated, high throughput multiplex assays
- Novel test formats and devices (POC)
- Complex signal deconvolution

**Large Datasets, Standardization and New Computational Analytics**
platform agnostic perspective

but

unit cost and compatibility with clinical practice will be highly influential in adoption
– screening tests versus clinical evaluation
– convenience and acceptance by physicians and patients
– value proposition for payors

and

need to address anticipated barriers to approval/adoption
– regulatory
– clinical conservatism/education
– displacement of existing Dx platforms/installed capital base
When testing for HER2

A second test may change her treatment

Because of tumor heterogeneity and assay limitations—
consider a second test

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Genentech
A Member of the Roche Group
IOM Committee Will Probe Duke Scandal Together With Other "Omics" Case Studies

By Paul Goldberg

A committee of the Institute of Medicine will refrain from launching a police-style investigation of the Duke scandal, the group's chairman said.

"We are not an investigative body," said Gilbert Omenn, director of the University of Michigan Center for Computational Medicine and Biology and chairman of the IOM committee. "I think we are heading into a morass, to try to figure out what really happened at Duke and who should bear responsibility and who should be held accountable."

At its first meeting Dec. 20, the 19-member group struggled publicly to interpret its charge and design a plan for deriving science policy lessons.

(Continued to page 2)
Standards

- pervasive end-to-end problem: from sample to answer
  - biospecimen acquisition, handling and storage
  - pre-analytical and analytical methods, data analysis and databanks
  - QC/QA of multiplex assays/equipment
  - trial design(s)
- role of professional societies, publishers and payors in raising the evidentiary bar
  - CONSORT, REMARK, STARD, STROBE, MIAME
- full disclosure as prerequisite for replication and evidence-based meta-analytics
- increasing omission of key ‘methodological data’ as handicap to meta-analytics
Will Rapid, Low Cost Genome Sequencing Change Everything?
Prepare for the “Tsunami of Genomic Information”
ASCO Presidential Address: Dr. George Sledge
Chicago, 5 June 2011

- “the day when a patient walks into her oncologist’s office carrying a memory stick containing personal genomic information could be less than a decade away”
- “when data are that cheap….things will get very, very complicated”

Exome- or Whole Genome Sequencing

Disease-Associated Perturbations in Pathways and Networks
Next-Next-Generation Sequencing?

- disposable USB pocket-sized sequencer
- $500-1000 unit
- 150 Mbp sequence/hour
- smaller instrument versus pending benchtop GridION 2K machine

Oxford Nanopore
MinION Sequencer

Life Technologies Ion Proton DNA Sequencer
Cost $149,000
Availability Mid-2012
The Cost of Sequencing
Versus
The Cost of Computational Analysis and Storage

- the $1000 genome,
  - the $? analysis and interpretation cost
  - the $? storage, retrieval and security costs
- turn around time (TAT) and analysis for clinical value cost
- regulatory and reimbursement policies
- obligations/duties to recontact/deidentify research participants/patients regarding Incidental Findings (IFs) and Individual Research Results (IRRs) detected in WES/WGS?
The Adoption of Genome Sequencing in Clinical Diagnostics

- from research odysseys to routine clinical use ("just another lab value!")

- early clinical applications
  - infectious diseases
  - hereditary cancers and individual risk assessment
  - oncology
  - rare diseases of suspected genetic etiology
  - HLA profiling for transplant matching
  - cardiomyopathies
  - X-linked intellectual disability
  - congenital muscular dystrophy
  - mitochondrial disorders
High Throughput WGS for Personalized Oncology

Low Cost Whole Genome Sequencing and Molecular Medicine: Dependency on Large Scale (Massive) Data Annotation and Analytics

- correlation analytics
  - SNPs, haplotypes
  - CNVs
  - rearrangements
  - non-coding regions
  - ethnic diversity
  - epistasis
  - epigenetics
  - other ‘omics’

- decision analytics
  - Rx response/resistance - target(s), networks
  - Rx adverse event risk
  - prognosis/progression
  - predisposition to disease
  - environmental exposure/lifestyle confounders for predisposition

- technical standards
- regulatory requirements
- reimbursement
- physician education

- privacy and security
- technical standards
- regulatory requirements
- reimbursement
- physician education
- minimum sequencing depth for reliable clinical decisions
- appropriate validation sample sets to evaluate platform accuracy
- metrics for quality of sequence assembly and alignment algorithms
- standardization of pre-analytical variables (e.g. preparation of libraries, extraction and quality control of nucleic acids, capture methods, amplification)
- source computer code(s) for analytical algorithms
- sequencers as Class III devices?
The Scale and Complexity of Human Genome Sequencing Data

**Accuracy and Comprehensiveness**

- need for consensus metrics for these parameters
- population-based studies
  - pooled samples with low depth coverage (<10x)
- personal genomes for clinical diagnostics and care decisions
  - greater accuracy and confidence for base calling
  - regulatory oversight of QA/QC and analytics algorithms
- current technologies
  - 30-40x coverage to ID 92-95% of both alleles
  - 50-100x coverage to ID 99.9% sequence and rare variants
  - final sequence with only 1 error/10^6 bases will still contain 6000 errors
Performance Comparison of WGS Platforms

- Sequencing of blood and saliva samples from the same individual on Illumina and Complete Genomics Platforms at 76x coverage.
- Only 88.1% SNVs concordant ≡ 10,000s platform-specific calls in exons and intergenic regions.
- Need to supplement with exome sequencing to fill gaps in detection of coding variants.
- Only 26.5% indels concordant.
- Implications for use of WGS data for clinical decisions/regulatory submissions.
<table>
<thead>
<tr>
<th>Variant Frequency</th>
<th>N=100</th>
<th>N=200</th>
<th>N=500</th>
<th>N=1000</th>
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<tbody>
<tr>
<td>0.001</td>
<td>0.18</td>
<td>0.33</td>
<td>0.63</td>
<td>0.86</td>
</tr>
<tr>
<td>0.002</td>
<td>0.33</td>
<td>0.55</td>
<td>0.86</td>
<td>0.98</td>
</tr>
<tr>
<td>0.005</td>
<td>0.36</td>
<td>0.86</td>
<td>0.99</td>
<td>1.00</td>
</tr>
<tr>
<td>0.01</td>
<td>0.86</td>
<td>0.98</td>
<td>1.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>

The Data Storage Challenge: The Price of Sequencing is Falling Faster Than Computer Storage Costs and Availability

- data ‘triage’: store only data deemed relevant and/or with differences to reference set
  - risk of bias/ignorance about value of discarded data elements

- data compression and ‘loss of precision’
  - different compression methods depending on desired end use/reuse needs

- unmapped reads cannot be compressed using current alignment frameworks
  - 10-40% of reads remain unmapped to traditional reference genomes
  - 60-70% for short RNA sequencing reads

- many samples may not be accessible/renewable
  - cancer
collection, use and governance of exome- and WGS information
  - genetic/genomic databases and biobanks
  - role of health IT

privacy and access

balancing of individual and societal interests

access and use by law enforcement agencies
“The Incidentalome”

- 2012 NIH proposal for screening exome-and WGS sequence data for findings of potential health or reproductive importance
- obligation to recontact/deidentify individuals in research studies
- criteria for “relevant” and “risk” in returnable findings?
- requirement to reidentify original donor in deidentified samples?
- resources and cost to implement with anticipated rapid growth in datasets?
- why limit to genomic research using biobanks and archived data?
- if research participants are accorded duties why not all patients sequenced as part of clinical care?
- expanded IRB responsibilities and competencies
Genes For.....
The Overly Simplistic and Deterministic Dangers of a Genome-Sequence Centric Perspective

- limits of current knowledge of genome organization and control dynamics
  - relationship to RNA regulome, protein expression and (in)stability of biological pathways
- limited value for robust predisposition profiling (epistasis......)
- variable utility in different disease categories to inform optimum Rx treatment choice and guide new Rx discovery
Individual Variation, Genome Complexity and the Challenge of Genotype-Phenotype Prediction

Junk No More!

- pervasive transcription
- alternate transcription
- SNPs, CNVs
- indels, SVs
- ncRNAs
- phasing
- epistasis
- imprinting
- silencing

Cell-specific Molecular Interaction Networks

recognition of genome organizational and regulatory complexity

Disease Perturbations
Mapping Causal Perturbations in Molecular Pathways and Networks in Disease: Defining a New Taxonomy for Disease

Disease Profiling to Identify Subtypes (+ or - Rx Target)

ID Molecular Targets for MDx and/or Rx Action

Cell Signaling...
The Heterogeneity of Biological Pathway Dysregulation in Different Diseases

- frequency of Rx susceptible ($\text{Rx}^s$) and resistant ($\text{Rx}^r$) phenotypes in different diseases and changes with disease progression
- implications for level of inter-patient variation and complexity of MDx profiling requirements
Scenario-Modeling of NPV for New Investigational Drug Based on Probability of Technical and Regulatory Success (PTRS) and Biomarker Patient Selection


http://www.nature.com/nrd/journal/v10/n11/pdf/nrd3557.pdf
Frequencies of Molecular Alterations in CRC and Responsiveness to Cetuximab or Panitumumab

Mutational Complexity of Acute Myeloid Leukemia

From: J. P. Patel et al. (2012) NEJM 366, 1079
Intratumor Genetic Heterogeneity in Multiple Regions at Primary Clear Cell Tumor and Three Metastases (Perinephric and Chest Wall)

From: M. Gerlinger et al. (2012) NEJM 366, 883
Initial Response (A/B) of BRAF-V600 Positive Metastatic Miliary Melanoma After 15 Weeks Therapy with Vemurafenib (Zelboraf® - Roche) Followed by Rapid Recurrence of Rx-Resistant Lesions with MEKI C1215 Mutant Allele After 23 Weeks Therapy

From: N. Wagle et al. (2011)
J. Clin. Oncol. 29, 3085
Mapping Dysregulation of Biological Networks in Disease

Disease Profiling to Identify Subtypes (+ or - Rx Target)

ID Molecular Targets for Rx Action and Blockade of Compensatory “By pass” Pathways
Network Pharmacology

- elucidation of definitive network ‘chokepoints’ as optimum targets
  - subvert adaptive cellular options to use alternate compensatory pathways

- the design challenge for multi-target polypharmacology
  - multi-agent therapy (patient tolerance?)
  - controlled multi-target promiscuity in a single moiety
## Mandatory Use of Research Biopsies in Clinical Trials?

<table>
<thead>
<tr>
<th>Time Point</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-enrollment/Pre-treatment</td>
<td>• ID of biomarkers to determine eligibility</td>
</tr>
<tr>
<td></td>
<td>• patient stratification in enrichment/adaptive clinical trial design</td>
</tr>
<tr>
<td>During Treatment Protocol and/or Post-Protocol Termination</td>
<td>• evaluate biomarkers/biosignature profile and Rx responsiveness</td>
</tr>
<tr>
<td></td>
<td>• identify mechanisms of acquired resistance to investigational Rx</td>
</tr>
</tbody>
</table>
Is the scale of pathway dysregulation in progressive late stage multigenic diseases too large to achieve Rx “homeostatic reset”? 

Should MDx priorities in cancer, neurodegeneration and diabesity be best directed to earlier disease detection rather than stratification of patients with advanced disease?
# Phase III Studies Comparing Chemotherapy With or Without Bevacizumab as First-Line Therapy for Advanced Epithelial Cancers

<table>
<thead>
<tr>
<th>Neoplasm</th>
<th>Study</th>
<th>Bevacizumab Effect</th>
<th>PFS (months)</th>
<th>OS (months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breast</td>
<td>ECOG E2100</td>
<td>+5.9*</td>
<td>+1.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>AVADO</td>
<td>+0.8*</td>
<td>-1.1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>RIBBON-1</td>
<td>+2.9*</td>
<td>+7.8</td>
<td></td>
</tr>
<tr>
<td>Ovarian</td>
<td>GOG 0218</td>
<td>+0.9</td>
<td>-0.6</td>
<td></td>
</tr>
<tr>
<td>Lung</td>
<td>ECOG E4599</td>
<td>+1.7*</td>
<td>+2.0</td>
<td></td>
</tr>
<tr>
<td>Gastric</td>
<td>AVAGAST</td>
<td>+1.4*</td>
<td>+2.0</td>
<td></td>
</tr>
<tr>
<td>Pancreas</td>
<td>CALGB 80303</td>
<td>+0.9</td>
<td>-0.1</td>
<td></td>
</tr>
<tr>
<td>CRC</td>
<td>Hurwitz</td>
<td>+4.4*</td>
<td>+4.7*</td>
<td>+1.4</td>
</tr>
<tr>
<td></td>
<td>Saltz</td>
<td>+1.4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Statistically significant
American Society of Clinical Oncology Provisional Clinical Opinion: The Integration of Palliative Care into Standard Oncology Care

Thomas J. Smith, Sarah Temin, Erin R. Alesi, Amy P. Abernethy, Tracy A. Balboni, Ethan M. Basch, Betty R. Ferrell, Matt Loscalzo, Diane E. Meier, Judith A. Paice, Jeffrey M. Peppercorn, Mark Somerfield, Ellen Stovall, and Jamie H. Von Roenn
Opportunities and Challenges for MDx for Ever Earlier Detection of Major Diseases

<table>
<thead>
<tr>
<th>Cancer Detection Before Metastasis</th>
<th>Cardiovascular/Metabolic Diseases</th>
<th>Neurodegenerative Diseases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early Diagnosis and Curative Surgery</td>
<td>Lifestyle Changes and/or Rx to Limit Risk</td>
<td>The Dilemma of Early Diagnosis Without Rx</td>
</tr>
</tbody>
</table>

**Diabetes + Obesity = DIABESITY**

By [TheAnarestPharmacist.com](http://TheAnarestPharmacist.com)
Defining The Molecular Taxonomy of Disease

- subtypes of disease
- individual segmentation and unique patient-specific perturbations in biological networks
- increased segmentation and what will constitute an orphan disease?
- ‘the incidentalome’
- longitudinal tracking of health status and early detection of disease
Individual Biosignature Profiling Via Sensors and Devices

Remote Health Status Monitoring
m.Health

Remote Health Monitoring and Chronic Disease Management

Lifestyle and Fitness

Information for Proactive Health Awareness (Wellness)
MicroCHIPS drug delivery and sensor technology both leverage the ability to microfabricate multiple wells into a microchip, and integrate that into an implantable device that uses these wells to deliver drugs or sense various analytes. Much like existing pacemakers and other implantable devices, the MicroCHIPS device also communicates wirelessly, allowing both control of the device and data transmission.

The device is implanted subcutaneously (under the skin) in a simple outpatient procedure using local anesthesia, and a small incision. The device is inserted much like a pacemaker with a couple of sutures to prevent device movement.
Remote Health Status Monitoring of Biometrics and Biomarkers Using Body Sensors and Devices (m.Health)

- Self-Tracking
- Personal Informatics
- Quantified Self
- Lifelogging
- LifeStream
- The Measured Life

NodeXL maps of tweets about Quantified Self
Posted on January 26, 2011 by Alexandra Carmichael
Mobile Devices, Remote Health Monitoring and Rapid Data Expansion

- expand concept of biobank to include ‘virtual and living repositories’
- individual becomes their own control
  - longitudinal monitoring of individual ‘deltas’ versus comparison with averaged larger cohort
- rich data streams for outcome analysis and epidemiological studies
  - consent, privacy and security
  - compliance monitoring
Data: The Fastest Growing Resource on Earth
Managing Massive Data

Standards for Data Reporting and Database Design

Interoperability of Databases Across The Continuum from Discovery to Patient Care

New Analytics and High Performance Computing
Silos Subvert Solutions: Protecting Turf and Sustaining the Status Quo

HELL IS THE PLACE WHERE NOTHING CONNECTS — T.S. ELIOT
The Need for Facile, Seamless Data Exchange Formats for Large Scale Biomedical Data Systems
The Design Challenge for Next Generation HIT Systems

- today EHRs not designed to support secondary use of data to inform research/translational medicine
- lack of harmonized data standards in different disciplines/delivery systems as handicap to data meta-analytics outside of original capture institution
- urgent need for new data integration models
  - current and planned RCTs
  - observational data from primary care provider and patient self-reported data
  - SEER (surveillance, epidemiology and end results) data
  - m.health/sensor net remote data monitoring
  - payer data
Representation of Datasets and Abstractions

Discovery
- controlled vocabularies and formal ontologies
- minimal information checklists and open source repositories
- algorithms and source code for analytical tools

Translation and Adoption in Routine Care
- exchange formats and semantic interoperability
- cross-domain harmonization/integration/migration/sharing
  - community-driven (eg. SMBL.org, BioSharing catalogue),
    industry-driven (eg. Pistoia Alliance), regulatory-driven (eg. CDISC),
    clinical (eg. HL7)
  - reimbursement (CPT, ICD) and HITECH EMR/MU
- consent, privacy, confidentiality, security
- meta-data tools
- machine-based natural language processing and decision support algorithms
Healthcare Data in the Cloud: Security, Confidentiality and Access
Technology Acceleration and Convergence: The Escalating Challenge for Professional Competency, Decision-Support and Future Education Curricula
Overcoming Gaps in Physician Knowledge of Molecular Medicine and a Paper-Centric Healthcare System

- 90% of Americans lack confidence in their clinicians’ ability to understand and use genetic information
- professional cultural vulnerability/reluctance to acknowledge
- refuge in outdated SOC/guidelines that fail to integrate much new molecular profiling data
- protracted deliberations by professional societies/boards
- less than 4% of 8967 ACGME programs relate to genetic expertise (JAMA 2011 306, 1015)
- MD curriculum/CME challenges
- generational gap in IT use/facileness and resistance to computerized decision-support tools
New Partnerships to Advance Clinical and Observational Trials on Biomarkers as a Foundational Element of Molecular Medicine

- Public-private partnerships and pre-competitive consortia to establish analytical and data standards
- Industry collaboration to validate disease-specific biomarkers in clinical trials
- Use of aggregated EMR and observational data to validate biomarkers and CER
- Social media and patient advocacy groups as catalysts to accelerate clinical trials and CER
BATTER-UP: Biomarkers of Anti-TNF Treatment Efficacy in Rheumatoid Arthritis-Unresponsive Populations
use of aggregated EMR data to facilitate clinical research
Proactive Engagement of Patient Communities in Investigational Clinical Trials and Observational Outcomes Studies

- Collate, Annotate, Curate and Host Clinical Trial Data with Genomic Information from the Comparator Arms of Industry- and Foundation-Sponsored Clinical Trials
- Building a Site for Sharing Data and Models to evolve better Disease Maps.

CYCORE CYber-infrastructure for COMparative Effectiveness REsearch

PURPOSE
To improve cancer-related comparative effectiveness research by better capturing data on physiological, behavioral and psychological status from research participants at home and as they go about their daily lives.
Why LDTs and IVDs May Become MIA

● draft guidelines (1 June 2011)
  – prohibit sale of research use only (RUO)/Investigational Use Only (IUO) products based on “reason to know” that will be used on clinical samples

● need for greater clarity of guidelines for regulatory approval
  – IVDMIA validation
  – WES and WGS validation
  – MDx: Rx combinations
  – MDx profiling for investigational Rx combinations
  – mandatory biopsy profiling for oncology trials
How Much New Technology Can We Afford?
Personalized Medicine:
Trends and prospects for the new science of genetic testing and molecular diagnostics

Working Paper 7
March 2012

Crossing the Three Chasms:
Complex Molecular Testing and Medicare Regulations

By Bruce Quinn M.D., Ph.D.
If You Build It, Will They Pay?
If It Isn’t Billable, It Won’t Happen!

- #1 will test alter patient management?
  - reduce cost of care
  - improve outcomes
- #2 what additional resources/services/training are affected by test adoption?
- #3 perception of RCT as only ‘gold standard’
  - narrow interpretation that discounts value of observational studies
- #4 payer demand for regulatory approval to be eligible for reimbursement or CED
- #5 mindset of ‘lab data’ as low cost (<1% total cost) despite role in most treatment decisions (>85%)
  - unianalyte versus multiplex tests
  - outdated US reimbursement codes
The Key Strategic Elements in the Evolution of Molecular Medicine

- Molecular diagnostics for disease prediction, prevention, earlier detection
- Biomarkers for health status profiling
- Risk management
  - Prevention
  - Disease subtyping and Rx choice
  - Compliance
  - m.health
- Molecular medicine
- Health status monitoring
- Optimized decisions
  - e.care: EMR, PHR
  - Integrated care and wellness
- m.health

- Integrated care and wellness
Raise standards for preclinical cancer research

C. Glenn Begley and Lee M. Ellis propose how methods, publications and incentives must change if patients are to benefit.
the potential economic and health benefits from biomarkers for molecular diagnostic profiling transcend any other current category of healthcare innovation
realization of this potential will not be straightforward and will require:

- improved technical standards for biomarker R&D
- sophisticated integration of complex multidisciplinary expertise (from silos to systems)
- proactive (inter)national leadership to establish comprehensive resources for biobanks, cyberinfrastructure and HIX data inter-operability
- new clinical trial designs for Rx/MDx combinations
- more frequent updating of SOC guidelines to reflect disease subtypes and patient heterogeneity
• clarity and faster responsiveness of regulatory frameworks to address new MDx technologies
• new reimbursement models for next-generation complex MDx tests that reflect R&D risk, cost and value
• “Crossing the Three Chasms” (B. Quinn)
  – Medicare billing rules
  – coding and reimbursement rules
  – coverage for innovative technologies