The Triumph of Clinical Integration

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Disclosures

- Co-developer: *Tracking, Trajectory and Trigger* tool ($T^3$)
- Medical advisor: *Etiometry LLC, Boston MA*
- Co-Developer: [www.RiskyBusiness.events](http://www.RiskyBusiness.events)
Wilma Rudolph; 3 gold medals, Rome Olympics 1960

“The triumph can’t be had without the struggle”
Humans, Technology & Data Science
Clinical Integration - Precision Critical Care: Understanding the problems and how we work.

Practice variability: Humans & systems

Admission
- Disease
- Procedure
- Acuity Index

Guidelines / Protocols
Early warning systems
Quality Metrics

Sources of Truth

Environment
Teams
Work flow

Discharge
- Mortality
- Morbidity
- Quality of Life

Monitoring devices

EHR

Patient & Unit VIEW
Decision making is a Dynamic process:

Quadrants for Adapting to Uncertainty™

- **Adaptive Behavior**
  - **Legal**: Low uncertainty / complexity
  - **Illegal-Normal**: Little adaption
  - **Resilience**: Shift clinical behavior
  - **Inappropriate Rigidity**: High uncertainty / complexity

*Patricia Trbovich PhD*
HumanEra,
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The diagram illustrates the relationship between adaptive behavior, situation uncertainty, and outcomes. It divides the space into four quadrants:

- **Adaptive Behavior** vs. **Situation Uncertainty**:
  - **High Adaptive Behavior, High Uncertainty**: Resilience
  - **High Adaptive Behavior, Low Uncertainty**: Legal
  - **Low Adaptive Behavior, High Uncertainty**: Inappropriate Rigidity
  - **Low Adaptive Behavior, Low Uncertainty**: Illegal-Normal

On the right side of the diagram, there is a graph showing the volume of outcomes with higher uncertainty or complexity. It indicates the need for predictive practices, adaptation, and understanding deviation.
Know your “space”: Dynamic, changes constantly
Precision Critical Care: Understanding the problems and how we work

Sources of Truth
- Environment
- Teams
- Work flow

Physiologic variability
- Risk Adjuster
- Disease
- Procedure
- Acuity Index

Education & AI
- Guidelines / Protocols
- Early warning systems
- Quality Metrics

Admission
- Monitoring devices
- Patient & Unit VIEW

Discharge
- Outcomes
- Benchmarks
- Mortality
- Morbidity
- Quality of Life

EHR
New tools for learning and transferring information.....

The Stanford Virtual Heart – Revolutionizing education on congenital heart defects
What has been the clinical impact?

Estimated <0.1% in routine clinical use

Business Intelligence: Improve operational & safety-related decision support
• Monitoring of key quality & performance indicators

Precise population-based care:
• Data-driven clinical care and management throughout the patient journey

Individualized patient care:
• Diagnosis, trajectory and prognosis, & decision support
Big data in healthcare

Data Commons: facilitate access and organization of various structured and unstructured data and enable real-time algorithms and analysis.
All patients (ownership) All data Permanently

Clinical use Research Training / labelling

Modelling Iterative

Visualization

Information Trajectory

Understanding New knowledge

Interactive Scalable Platform

Usable: Augment decision making
Data Flow

- CCCU / PICU (42 Beds)
  - 5 second Data
  - Waveform / 1 Second Data
  - Ventilator / other data

- Server: Philips Gateway Server
  - Role: Hosts HL7 5s device metric data feed
  - Serial Connection to Philips Monitors

- Server: HSC EMR Servers
  - Role: Provides HL7 feed of patient lab information
  - Provides ADT database access

- Server: T3 Production
  - Role: Short-Term Data Storage
  - Web Interface Hosting

- Server: T3 Analytics
  - Role: Long-Term Data Storage
  - Analytics Engine

- Server: T3 Staging
  - Role: Testing / Evaluation of New T3 Software

- Server: VINES Server
  - Role: Device bridge and data aggregator for waveform and 1 second metric data

- Server: Laboratory Information System
  - Role: T3 User Interface Web-Browser
  - T3 Production Software
  - Test T3 User Interface Web-Browser
  - Test T3 Production Software

- Server: AtriumDB
  - Role: Permanent storage of device metric and waveform storage
  - Analytics Engine
  - Programming Interface
  - Web User Interface Hosting

- Server: AtriumDB Analytics Engine

- Server: AtriumDB Web User Interface

- Server: VINES
  - Role: Physiological Database

- Server: HPC4Health
  - Role: Large Scale Compute Capability
  - Secure Access to Data for External Collaborators

- Server: HPC4Health
  - Role: High Speed Private Physical Connection

Lower frequency data (5 second)

- Server: HSC EMR Servers
  - Role: Hosts HL7 5s device metric data feed

- Server: ADT via Oracle Database
  - Role: Provides ADT database access

- Server: T3 Analytics Server
  - Role: Infusion / other data feeds

- Server: T3 Risk Analytics Software

- Server: T3 Production Server
  - Role: T3 Production Software

- Server: T3 Staging Server
  - Role: Testing / Evaluation of New T3 Software

- Server: HPC4Health
  - Role: Large Scale Compute Capability
  - Secure Access to Data for External Collaborators

High frequency data
Volume of Water
~200,000 ft³/sec

Volume of Physiologic Data
~200,000 bytes/sec

Data Management System

- Application interface(s)
- Time Series Compression: Adaptive compression and file index
- Signal Quality Index: Measured coefficient of variance
- Signal generation & processing

Efficient storage and retrieval; Analysis ready

Predicting a PHYSIOLOGIC STATE

**HII (Hemodynamic Instability Index)**
*likelihood* that intervention is needed based on hemodynamic instability defined as requiring a fluid bolus or initiation vasoactive drugs. Range: 0 and 1.

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**IDO2 (Inadequate Oxygen Delivery Index)**
*likelihood* that the patient is experiencing inadequate oxygen delivery, defined as mixed venous oxygen saturation (SvO2) less than 40%. Range: 0 and 100.
Prediction of EVENTS

Sepsis

Cardiac Arrest
Signal processing

"Atrial Fibrillation Classification Using Step-By-Step Machine Learning".
Goodfellow, Sebastian; Goodwin, Andrew; Greer, Robert; Laussen, Peter; Mazwi, Mjaye; Eytan, Danny. Biomedical Physics & Engineering Express.
More subtle phenomena......

• “Hidden variables”- things not easily measured directly at bedside (variability measures, SVR, oxygenation parameters, autoregulation)
We need......

• Multi-modal and multi-site Physiologic Databank
• Data management platform:
  - 4R’s: relational, reliable, robust and retrievable (beyond the 4 V’s)
• Linkages established with categorical registries and other sources of data
• APIs written => Distributive computing ready
• Governance structure, shared, open source (democratized)
• Knowledge translation and implementation

Pediatric cardiac critical care well placed to realize this
Expanded teams and expertise

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