Personalized Physiological Models in Intensive-Care Medicine

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In collaboration with
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Intensive-Care Medicine

- Patients’ bodies not functioning normally, would die otherwise
  - ~200 medical procedures per day per patient
- US ICUs:
  - 5 million patients per year, 500,000 die
  - $200-400B/year (comparable to world semiconductor industry)
Intensive-Care Medicine

- Patients’ bodies not functioning normally, would die otherwise
  - ~150 medical procedures per day per patient
- US ICUs:
  - 5 million patients per year, 500,000 die
  - $200-400B/year (comparable to world semiconductor industry)
- Goal: 50% reduction in mortality, length of stay
Approach

- Data:
  - Continuous, high-frequency physiological data
240Hz, ~40 variables, ~200 hours
Approach

- **Data:**
  - Continuous, high-frequency physiological data
  - Sporadic data on interventions, drugs, lab analyses
Approach

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- Methods:
  - Patient-adaptive models of physiology and disease state
    - Dynamic Bayesian networks as a core, generic computing technology
    - Data refine the patient-specific model and state estimate over time
1970s: physiology models = deterministic differential equations

10% of Guyton 1972
2010s: probabilistic physiology/sensing

- Perfect models + perfect data = perfect predictions
- Real world: incomplete models, noisy data, sick patients
- Probabilistic models bridge the gap; allow for uncertainty in
  - Underlying physiological knowledge
  - Properties and state of specific patient
  - Actual measurements
- ITFoM seems prepared to
  - Embrace a probabilistic methodology
  - Develop the computational technology to support it
Approach

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- **Results**
  - Reduced ICU false alarms from 90% to 5% (UCB/UCSF)
  - Detection of TBI cerebral edema, autoregulation failure, etc
  - Noninvasive intracranial pressure measurement (UCLA, MIT)
  - Reduced neonatal sepsis mortality (UVA)
  - Substantially improved neonatal prognosis score (Stanford)
Physiscore: novel tool for risk prediction

- Identifies premature infants at risk for major complications

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<tr>
<th></th>
<th>APGAR (Standard of care)</th>
<th>CRIB</th>
<th>SNAP-II</th>
<th>SNAPPE-II</th>
<th>Physiscore (Our tool)</th>
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</thead>
<tbody>
<tr>
<td>Time from birth</td>
<td>5 mins</td>
<td>12 hours</td>
<td>12 hours</td>
<td>12 hours</td>
<td>3 hours after birth</td>
</tr>
<tr>
<td>Accuracy</td>
<td>0.69</td>
<td>0.85</td>
<td>0.82</td>
<td>0.87</td>
<td><strong>0.91</strong></td>
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<tr>
<td>Invasive testing</td>
<td><img src="image" alt="X" /></td>
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Saria et. al, *Integration of Early Physiological Responses Predicts Later Illness Severity in Preterm Infants*, Science Trans. Med. 2010 (Cover article)
Next steps

- Complete high-level physiology model for all systems
  - Quantified uncertainty from populations, experimental studies
    - Notation standards for uncertain models
    - Data collection standards for all ICUs (IMEDES consortium)
  - Demonstrate accurate inference of all key disease states
  - Demonstrate accurate therapy planning

- Connect to more detailed molecular/finite-element models
  - Integrate –omic and imaging data into predictions
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- Detailed modeling works for looking after nuclear warheads; it can work for humans too