Advance Alert Monitor Variables
Designed to predict an ICU transfer or unexpected death in the next 12 hours

<table>
<thead>
<tr>
<th>Laboratory</th>
<th>Vital signs</th>
<th>Patient &amp; hospital factors</th>
<th>Composite indices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anion gap</td>
<td>Diastolic BP</td>
<td>Age</td>
<td>LAPS2 – acute severity of illness</td>
</tr>
<tr>
<td>Bicarbonate</td>
<td>Systolic BP</td>
<td>Gender</td>
<td></td>
</tr>
<tr>
<td>Glucose</td>
<td>Heart rate</td>
<td>Care directive</td>
<td></td>
</tr>
<tr>
<td>Hematocrit</td>
<td>Oxygen saturation</td>
<td>Length of stay</td>
<td>COPS2 – chronic comorbidity score</td>
</tr>
<tr>
<td>Lactate</td>
<td>Respiratory rate</td>
<td>Season</td>
<td></td>
</tr>
<tr>
<td>Blood urea nitrogen</td>
<td>Temperature</td>
<td>Time of day</td>
<td></td>
</tr>
<tr>
<td>Creatinine</td>
<td>Shock index</td>
<td>Admission type</td>
<td></td>
</tr>
<tr>
<td>Sodium</td>
<td>Neurologic status</td>
<td>Hospital facility</td>
<td></td>
</tr>
<tr>
<td>Troponin</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WBC count</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Journal of Hospital Medicine 2017
Designing integrated clinical response pathways
Establishing standardized processes and timelines for alert response

Alert time-zero

Within 1 hour
- eHospital chart review
- Call to local RRT nurse

Within 3 hours
- RRT RN talks to 1° RN
- Vitals re-evaluation
- Calls 1° MD with SBAR

Within 6 hours
- MD evaluation/diagnosis
- Communicate plan with team
- Consult social services/palliative care

Before hospital discharge
- Social services reviews charts to ensure documentation of decision-maker
- Additional services, if appropriate
Improving AAM patient-provider communication
Helping patients understand how our tools are designed to enhance clinical practice

A Big Data model is predicting how poorly you'll do in the next 12 hours...

An advanced computer system is monitoring you...

Our algorithms show that your risk of requiring the ICU or dying is 18.4%...
Interim results of AAM Beta Pilots
Deployment based on 1\textsuperscript{st}/2\textsuperscript{nd} generation EMR-external solution

<table>
<thead>
<tr>
<th>Matched groups</th>
<th>Alerted Patients in AAM Live Hospitals (n = 3,097)</th>
<th>Matched Patients in non-AAM Hospitals (n = 3,097)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inpatient mortality</td>
<td>8.8%</td>
<td>10.8%</td>
</tr>
<tr>
<td>30-day mortality</td>
<td>14.2%</td>
<td>16.4%</td>
</tr>
<tr>
<td>Decision-maker documented\textsuperscript{1}</td>
<td>76 – 95%</td>
<td>40 – 47%</td>
</tr>
</tbody>
</table>

\textsuperscript{1}Data from first 3 medical centers on 2\textsuperscript{nd} generation platform between 2016 to 2018
Roger’s Hospital Course – today with AAM

- **6 hours after admission:**
  - AAM system alerts
  - RRT RN, bedside RN, and covering MD evaluate Roger
  - Document their assessment with criteria for escalation

- **7 AM the next morning:**
  - Oncoming RRT RN conducts proactive AAM follow-up rounds
  - Roger is still confused, with worsened breathing
  - RN requests an arterial blood gas – Roger found to be retaining CO₂

- **8 AM:**
  - Based on the AAM score and her assessment, RRT RN calls the ICU team
  - They agree that Roger would benefit from ICU admission
Roger’s Hospital Course: towards recovery

• In the ICU that day:
  ▪ Roger was sedated, given antibiotics, and placed on BiPAP overnight

• By the next AM:
  ▪ Roger was off BiPAP and sitting with family
  ▪ Imaging showed a psoas abscess
  ▪ IR drained the abscess

• Two days later:
  ▪ Roger recovered and went home
Nurses and doctors are sometimes too busy to keep track of small changes in patients and AAM can pick these up before an RRT...

I want to be able to see the AAM scores directly so we can improve our own screening practice...

In my experience, about 20% of alerts turn out to be real...

I have so many stories like this of AAM working, where the score helps us to get to patients earlier...
AAM Regional Spread Approach
Timelines to prepare local facilities for AAM ‘go-live’

- **T-15 Weeks**
  - Notify hospital leadership

- **T-12 Weeks**
  - Kick-off regional-local meeting

- **T-10 Weeks**
  - Assess hospital readiness

- **T-8 Weeks**
  - Education & Training

- **T-2 Weeks**
  - Workflow Practice Runs

- **T+2 Weeks**
  - Huddles & Performance Improvement

- **-15**
  - Confirm timelines
  - Identify champions

- **-12**
  - On-site review
  - RRT/RN staffing
  - Service agreements

- **-10**
  - Hospital communication
  - Staff training

- **-8**
  - Simulate workflow
  - Daily huddles to address issues

- **-2**
  - Daily huddles
  - Weekly/Monthly performance reports

- **0**
  - AAM Live

- **+2**
  - AAM Live
The quest for workflow integration

eHospital staff currently have a highly disrupted workflow

AAM Interface
- Check for AAM alerts
- Review ancillary data

KPHC EMR
- Conduct primary EMR check
- Confirm patient & evaluate
- Evaluate pt chart for intervention

AAM Spreadsheet
- Check for prior AAM alerts
- Record patient data
- Record RN contact
- Identify prior AAM patients
- Document intervention occurred

Facility RRT RN
- Call facility RRT RN
- Check-in with RRT RN

Periodic Brownouts
Old, buggy code
Maxed out Platform

Beta
Alpha
Spread
Implement
**LAPS2, COPS2, and AAM scores**

KPNC-wide real-time risk scoring in production

<table>
<thead>
<tr>
<th>Score</th>
<th>Metric</th>
<th>C-statistic (Live)</th>
<th>KPHC stored values per day</th>
</tr>
</thead>
<tbody>
<tr>
<td>LAPS2</td>
<td>Acute severity of illness</td>
<td>0.84</td>
<td>~64,000</td>
</tr>
<tr>
<td>COPS2</td>
<td>Chronic comorbid disease burden</td>
<td>0.73</td>
<td>~400</td>
</tr>
<tr>
<td>AAM</td>
<td>Risk of ICU transfer or unexpected death among inpatients</td>
<td>0.76 (low outcome rate)</td>
<td>~45,000</td>
</tr>
</tbody>
</table>
Challenges in model validation

<table>
<thead>
<tr>
<th>Validation step</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Translating curated model parameters to real-time data</td>
<td>Lactate values</td>
</tr>
<tr>
<td>Simple transcription errors</td>
<td>SBP rules</td>
</tr>
<tr>
<td>Limitations to Epic properties</td>
<td>Ratios (shock index) Neuro scores</td>
</tr>
<tr>
<td>Timestamp data differences</td>
<td>All subscore values</td>
</tr>
<tr>
<td>Lack of decimal places in risk score output</td>
<td>AAM score alert threshold</td>
</tr>
</tbody>
</table>
Key Takeaways

- The promise of real-time predictive models is exciting
- Explicit conversations between Data and Delivery Science are needed
- Governance is needed to improve all aspects of model value
- The Epic platform offers advantages for integrated model deployment
- However, there are challenges in the platform
Special thanks to the KPNC AAM team!

KP Northern California: Phil Madvig, Barbara Crawford, Michelle Caughey, Steve Parodi, Theresa Brodrick

KP Division of Research: Gabriel Escobar, Patricia Kipnis, Arona Ragins, John Greene, Lauren Soltesz, Brian Lawson, Benjamin Turk, Juan Carlos LaGuardia

Operations: Shirley Paulson, Alex Dummett, Julia Green, Liesel Buchner, Elizabeth Scruth, Tamar Fendel, Lindsey Burbage


Physician and Nursing Leads across KPNC hospitals.