Engineering Work Systems to Improve Patient and Health Care Worker Safety

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We bring a scientific approach to reengineering health care systems and processes so that medical errors are "designed out" and evidence-based care is built in.

bit.ly/healthcarehumanfactors
www.hopkinsmedicine.org/armstrong/humanfactors
What is Human Factors and Ergonomics (HFE)?

“…the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance.”
Other Ongoing Projects

- Care transitions and teamwork in **pediatric trauma**: Implications for HIT design *(AHRQ R01)*

- Patient-centric approach to **medication safety during care transitions from hospital to home** *(AHRQ R01)*

- Applying HFE and mathematical modeling to **prevent transmission of high-consequence pathogens** *(CDC)*

- Infection control **training** modules (e.g., Ebola prevention, nursing modules) *(CDC)*

- System analysis of nurses’ adherence with the CLABSI maintenance guidelines in **neonatal intensive care** *(NICHD)*
Pediatric Trauma Care Transitions*

1. To describe cognitive teamwork involved in care transitions of pediatric trauma patients
2. To develop and test design requirements for future health information technology (HIT)

* Funded by the Agency for Health Care Research and Quality R01 (PI: Gurses)
Pediatric Trauma Patient Pathways
(Trauma registry, alpha & bravo)

26 different pathways

<table>
<thead>
<tr>
<th>Rank</th>
<th>Patient Pathways</th>
<th>Total N = 1772</th>
<th>Alpha N = 214</th>
<th>Bravo N = 1558</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Origin → ED → Discharge</td>
<td>767 (43.4)</td>
<td>23 (10.8)</td>
<td>744 (47.8)</td>
</tr>
<tr>
<td>2</td>
<td>Origin → ED → Floor → Discharge</td>
<td>553 (31.2)</td>
<td>30 (14.0)</td>
<td>523 (33.6)</td>
</tr>
<tr>
<td>3</td>
<td>Origin → ED → PICU → Floor → Discharge</td>
<td>136 (7.7)</td>
<td>52 (24.3)</td>
<td>84 (5.3)</td>
</tr>
<tr>
<td>4</td>
<td>Origin → ED → PICU → Discharge</td>
<td>107 (6.0)</td>
<td>26 (12.2)</td>
<td>81 (5.2)</td>
</tr>
<tr>
<td>5</td>
<td>Origin → ED → Floor → OR → PACU → Discharge</td>
<td>61 (3.4)</td>
<td>8 (3.7)</td>
<td>53 (3.4)</td>
</tr>
</tbody>
</table>
Pediatric Trauma Care: Role-Location Matrix

- Role-Location matrix: 58 total roles for 7 locations

<table>
<thead>
<tr>
<th>Location/Role</th>
<th>ED (Pediatric/Adult)</th>
<th>Surgery</th>
<th>Orthopaedics/Neurosurgery</th>
<th>Pediatric Intensive Care Unit (PICU)</th>
<th>Other</th>
<th>Support</th>
</tr>
</thead>
<tbody>
<tr>
<td>ED Trauma Bay</td>
<td>EM attending (Ped/Adult)</td>
<td>Ped EM fellow</td>
<td>EM resident (Ped/Adult)</td>
<td>Ped ED nurse-bedside</td>
<td>EM nurse-bedside</td>
<td>PICU attending/fellow</td>
</tr>
<tr>
<td></td>
<td>1, 2</td>
<td>1, 2</td>
<td>1, 2</td>
<td>1</td>
<td>1, 2</td>
<td>1, 2</td>
</tr>
<tr>
<td>Imaging (CT/MRI)</td>
<td>at least one; 1</td>
<td>1, 2</td>
<td>at least one; 1</td>
<td>at least one; 1</td>
<td>1, 2</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>1, 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating Room (OR)</td>
<td>at least one; 1</td>
<td>1, 2</td>
<td>at least one; 1</td>
<td>at least one; 1</td>
<td>1, 2</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>1, 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interventional Radiology (IR)</td>
<td>at least one; 1</td>
<td>1, 2</td>
<td></td>
<td>at least one; 1</td>
<td>1, 2</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>1, 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post-Anesthesia Care Unit (PACU)</td>
<td>at least one; 1</td>
<td></td>
<td></td>
<td>at least one; 1</td>
<td>1, 2</td>
<td>1, 2</td>
</tr>
<tr>
<td></td>
<td>1, 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pediatric Intensive Care Unit (PICU)</td>
<td>at least one; 1</td>
<td>1, 2</td>
<td>at least one; 1</td>
<td>1, 2</td>
<td>1, 2</td>
<td>1, 2</td>
</tr>
<tr>
<td></td>
<td>1, 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Floor</td>
<td>1, 2</td>
<td>1, 2</td>
<td>at least one; 1</td>
<td></td>
<td>1, 2</td>
<td>1, 2</td>
</tr>
</tbody>
</table>

*required per trauma protocol
Health IT Design: Characterizing the Information Needs

Excerpt of resulting themes

• Goals
• Attributes
• Data, Information & Knowledge
• Information Sources
• Access and Management
• Work System Factors
  – Barriers, Facilitators, Expertise, Organizational factors
• Consequences
• Design Implications
• Implementation Implications
Attributes of information needed

- Information structure
- Completeness
- Multi-role support
- Uncertainty
- Reliability
- Variations in priority

“…if the kid had an abnormal chest film and had an infiltrate, that could be a pulmonary contusion or it could be an aspiration, so then the right way to put that on the problem list is to put it on as a pulmonary infiltrate and say, ‘I don't know if it's blood or if it's an infection…and until you've got a degree of precision, you shouldn't be typing pulmonary contusion in because that's going to force people down-- that's going to lock people's mindset into the wrong…”

– PICU Attending
Putting the data to use
The problem with the ‘problem list’

- ‘Problem list’ not adequately supporting individual and team cognition and teamwork
  - Most convenient items, rather than the most reflective of patient condition, are selected, or none at all
  - No degree of uncertainty tied to a piece of information
  - Linkage between actions/treatments and ‘problems’ not easy to view

"The main consequence [of a poor problem list] would be that you forget about something. That you forget to put on the problem list that the patient had a splenic injury. But then they also might have a vascular injury and you want to put them on heparin. And you start them on heparin, a blood thinner, and then all of a sudden their spleen starts bleeding because you forgot they had a splenic injury too, except it wasn't on the problem list.”

– GPS Attending
### Epic (Health IT) ED Trauma Narrator

#### Focused Assessment
- Consult Needed: Yes (burn patient)
- Neurological - Neuro (WDL): Within Defined Limits
  - Glasgow Coma Scale (15 years): Eye Opening: Spontaneous; Best Auditory/Visual Stimuli: Response: Appropriate words or phrases; Best Motor Response: Obey; Glasgow Coma Scale Score: 15
- HEENT - HEENT (WDL): Within Defined Limits
  - Respiratory - Respiratory (WDL): Within Defined Limits
  - Cardiovascular - Cardiac (WDL): Within Defined Limits
  - Integumentary - Integumentary (WDL): Exceptions to WDL; Skin Integrity: Other (Comment) (open and intact blisters noted on chin, neck, chest and right axilla and right upper arm)
- Musculoskeletal - Musculoskeletal (WDL): Within Defined Limits
  - Gastrointestinal - Gastrointestinal (WDL): Within Defined Limits (last ate at 10pm)

#### Immunizations
- Child Immunization Status - Childhood Immunization Status: Up to Date

#### Assign Attending
- Assigned as Attending

#### Assign Physician

#### First Physician Assigned
- Humpty Dumpty Fall Risk: Age: Less than 3 years; Gender: Male; Diagnosis: Other Diagnosis; Cognitive Impairments: Forgets limitations; Environmental Factors: Patient placed in bed
- More than 48 hours/None; Medication Usage: Other Medications/None; Total Risk Score: 13
- High Fall Risk Interventions: High Fall Risk Interventions: Assess need for increased supervision
- New: Initiate Patient Triage, Assessment and Non-Prescriber Initiation Protocol Orders

#### Orders Acknowledged
- Safety/Orientation: Arrival: Brought to room on stretcher by EMS; Preparation: Patient placed on stretcher; Bed: Low in bed; Side rails up x 1; Call Light: Call light is within reach of family member; Person oriented to room and educated on fall risk: Father; Additional Risk Factors: Developmental; Fall Risk Interventions: Education on increased fall risk and prevention

#### Head to Toe
- Glasgow Coma Scale (15 years): Eye Opening: Spontaneous; Best Auditory/Visual Stimuli: Response: Appropriate words or phrases; Best Motor Response: Obey; Glasgow Coma Scale Score: 15
- HEENT - HEENT (WDL): Within Defined Limits
- Respiratory - Respiratory (WDL): Within Defined Limits; Respiratory Pattern/Rate: Normal; Bilateral Breath Sounds; Clear
- Cardiovascular - Cardiac (WDL): Within Defined Limits (2+ bilateral radial pulses. Afebrile.)
- Capillary Refill: LUE less than 3 seconds; RUE less than 3 seconds
- Integumentary - Integumentary (WDL): Exceptions to WDL; Skin Integrity: Other (Comment) (Open burn to bilateral.
Sample Preliminary Design Implications for Health IT solutions in Peds Trauma Care Transitions

- Presentation of patient information to see the entire “story” of the patient over time
- Ability to easily view summary/abstracted view of patient “story”
- Link all actions (orders, meds, procedures, etc.) back to the problem(s) they address
- Tailor presentation of information based on its relevance to context, patient case, role/team, experience level.
- Alternate input modes for information due to time constraints (e.g. verbal mode, scribes, sensors/data fusion)
- Display time factor – when things were done and when they should be done
- Graphs of vital sign trends and other health date (e.g., heart rate, weight)
- Data reduction/ information summary – Abbreviated version of care completed and care plan - only the most recent and relevant
- Support effective management of competing priorities
Design Sessions

Different Representations of Timeline of Events

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 PM</td>
<td>Car crash</td>
</tr>
<tr>
<td>4:15 PM</td>
<td>EMT arrive on scene</td>
</tr>
<tr>
<td>4:45 PM</td>
<td>Patient arrives in ED</td>
</tr>
<tr>
<td>4:55</td>
<td>Resuscitation starts</td>
</tr>
<tr>
<td>4:46 PM</td>
<td>Epinephrine injection</td>
</tr>
<tr>
<td>4:50</td>
<td>Resuscitation success</td>
</tr>
<tr>
<td>5:15 PM</td>
<td>transfer patient to OR</td>
</tr>
</tbody>
</table>

![Blood Pressure Graph]
Following with Evidence-Based Guidelines: Theory versus Practice

• Consistent compliance with evidence-based guidelines is challenging yet critical to patient and health care worker safety.

• Need for interdisciplinary approach to improve compliance

• From human factors point of view: Compliance as “systems property.”

• How to make it easy to follow guidelines given the realities of the world?
How to Improve Compliance with Guidelines?

1. Proactive risk assessment

   - Interviews
   - Observations
   - Task analysis
   - Simulations
   - Literature

   Identify risks

   Risk analysis (Focus groups)

   Assess & prioritize risks, develop solutions

2. Participatory and iterative nature of the intervention design

3. Multi-method evaluation

Improving Patient Room Cleaning Process*

- Using a participatory ergonomics approach to improve the daily patient room cleaning process
  - Collaboration among environmental care (EVC), infection prevention, and human factors
  - Involvement of EVC associates, EVC managers, and other healthcare workers (e.g., nurses)

*Funded by the CDC Epicenter Prevention
Assessment of the Cleaning Process

• Observations of 10 EVC associates performing daily cleaning of 89 patient rooms
Observation Results

<table>
<thead>
<tr>
<th>High touch surfaces in main room</th>
<th>% of rooms where surface was cleaned</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bedrail 4</td>
<td>30</td>
</tr>
<tr>
<td>Bedrail 2</td>
<td>40</td>
</tr>
<tr>
<td>Family chair</td>
<td>43</td>
</tr>
<tr>
<td>Bedrail 5</td>
<td>50</td>
</tr>
<tr>
<td>Cabinet</td>
<td>52</td>
</tr>
<tr>
<td>Visitor chair</td>
<td>57</td>
</tr>
<tr>
<td>Bedrail 3</td>
<td>58</td>
</tr>
<tr>
<td>Telephone</td>
<td>58</td>
</tr>
<tr>
<td>Patient chair</td>
<td>59</td>
</tr>
<tr>
<td>Side table</td>
<td>62</td>
</tr>
<tr>
<td>Remote control</td>
<td>64</td>
</tr>
<tr>
<td>Light switch</td>
<td>69</td>
</tr>
<tr>
<td>Bedrail 1</td>
<td>74</td>
</tr>
<tr>
<td>Soap dispenser</td>
<td>79</td>
</tr>
<tr>
<td>Sink</td>
<td>80</td>
</tr>
<tr>
<td>Over bed table</td>
<td>82</td>
</tr>
<tr>
<td>Door knob</td>
<td>84</td>
</tr>
<tr>
<td>Keyboard</td>
<td>85</td>
</tr>
<tr>
<td>Mouse</td>
<td>89</td>
</tr>
<tr>
<td>Supply cart</td>
<td>89</td>
</tr>
</tbody>
</table>

Window Ledge

- Patient chair (59%)
- Over bed table (82%)
- Family chair (43%)
- Cabinet (52%)
- Visitor chair (57%)
- Bed (50%)
- Telephone (64%)
- Call Box/Remote (64%)
- Bedrail 5 (50%)
- Bedrail 4 (30%)
- Bedrail 3 (50%)
- Bedrail 1 (74%)
- Bedrail 2 (49%)
- Side table (62%)
- Monitor (89%)
- Keyboard (85%)
- Mouse (89%)
- Sink (80%)
- Soap dispenser (79%)
- Door knob (84%)
- Light switch (69%)
- Supply cart (90%)

- >80%
- 60-80%
- <60%
## EVC Associate Workflow Patterns

<table>
<thead>
<tr>
<th>Workflow patterns</th>
<th>Direction of cleaning</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Clockwise</td>
<td></td>
</tr>
<tr>
<td>Bottom-up</td>
<td>13</td>
<td>20</td>
</tr>
<tr>
<td>Top-down</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

**Clockwise**
- Bottom-up: 13
- Top-down: 0

**Counterclockwise**
- Bottom-up: 20
- Top-down: 2

**Zigzag**
- Bottom-up: 12
- Top-down: 2

[Diagrams showing workflow patterns are included in the table.]
Areas for Improvement

Cleaning process
1. Huddle
2. Cart preparation
3. Patient room cleaning
4. Common areas cleaning

Work system elements
1. Safety culture
2. EVC teamwork
3. Teamwork with other healthcare workers
4. EVC leadership
5. Checklist and iPod
6. Training
7. Performance evaluation
NO MORE CART PROBLEMS!

At the beginning of your shift
Check Cart Out

At the end of your shift
Check Cart In

The Inventory Clerk stocks the carts overnight.

If you are missing supplies, check with your supervisor at the start of the shift.

Get to know your associate for the next shift.
Building Communication Structure Between the EVC and Nursing Teams

**Nurse Champion**
- Engage EVC associate on unit and unit activities
- For example: huddles, birthday celebrations, CUSP meetings

**Charge Nurse**
- Immediate (minor) issues on unit
- For example: patient issue, access to areas and supplies

**Nurse Manager**
- Ongoing (major) issues on unit
- For example: conflict with other HCW’s, supervisors, performance evaluation

**EVC associate**
THANK YOU!

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