The Science of How

Jeanne Huddleston, M.D.
$9.8 Billion*

*Cost of health care associated infections annually.
$4.5 Trillion*

*Projected spending on health care in America by 2019 (19.3% GDP).
Leadership: Problem Domains

- Capacity and resource management
- Safety (employee and patient)
- Workload and treatment optimization
- Process efficiency and reliable care delivery
- Systems integration across transitions of care
- Workforce projections with possible staffing models
- Workflow reorganization in new physical space
- Economic analyses with generation of novel payment models
- Patient-centered outcomes research
Process Improvement Approaches

- Basic Methods: Lean, Six Sigma, Plan-Do-Study-Act
- Necessary Overlap
- Engineering New Value
- SE/OR
  - Health Care Systems Engineering
  - Industrial Engineering
  - Operations Research
  - Management Science
  - Clinical Informatics

Purpose: Advancement of the Science of Health Care Delivery
Building the HSE Program

<table>
<thead>
<tr>
<th>HEALTH CARE DELIVERY</th>
<th>Engineering Methodological Expertise</th>
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| Hospital            | Simulation ★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★★
The Mayo Clinic Center for the Science of Health Care Delivery (2011)

To create, evaluate and implement high value patient-centric care delivery

Objectives

• Improve our delivery systems to provide high value and reliable care
• Increase our national leadership in value driven care delivery
• Disseminate our knowledge
• Execute the Mayo Strategic and Operating Plan
HEALTH CARE SYSTEMS ENGINEERING
Improving health care delivery systems, as well as increasing the efficiency and effectiveness of health care delivery, by applying engineering, management and translational science principles.

PATIENT-CENTERED OUTCOMES
Focusing on the entire patient journey to develop, study, test, implement and share new models of patient-centered health care delivery.

POPULATION HEALTH SCIENCE
Creating optimal health and well-being in an 11-county area in southeastern Minnesota by focusing on prevention and health promotion.

SURGICAL OUTCOMES
Improving the quality of surgical patient care at Mayo Clinic and in the U.S. with a focus on access, safety, quality and outcomes.

VALUE ANALYSIS
Studying the value of health care delivery at Mayo Clinic and other organizations by analyzing cost, utilization, quality, safety, patient-reported outcomes and other measures.

THEMES
Orthopedics, mental health and palliative care are priority areas within the center’s five programs.
Reducing Breast Lumpectomy Reoperation

Surgical Outcomes Program
Reducing Breast Lumpectomy Reoperation

Surgical Outcomes Program

National cohort: 13.2%
Mayo cohort: 3.6%
Collaborating to Achieve Value
Value Analysis Program
Total Episode Medicare Costs
Hip & Knee Replacement

Mayo Clinic

30 days after surgery
Initial hospitalization
Neurology Appointments

Forecast Implemented

- Unfilled Appts.
- Overbooks
- Days to 3rd Available Appt.
Perspectives to be considered
Problem

- More than 40% of a hospital’s revenue comes from Operating Rooms (Health Care Financial Management Association)
- ORs count for large proportion of hospital’s expenses
- Patient waiting time for surgery can be very high
- Highly variable OR utilization
- Spine surgeries are the most costly surgeries in the US (Agency for Healthcare Research and Quality)
- Spine surgeries ranked as the sixth most common surgeries in the US
Dynamic Facilitation of Flow

Ubiquitous signals at urban on-ramps help regulate the smooth flow of vehicles on to the freeway…

…thereby ensure that freeways operate at maximum capacity
Clinical Covariates = Face Validity

- Age
- Number of levels
- Approach
  - Anterior
  - Posterior
  - Lateral
  - Staged
- Cervical, thoracic or lumbar
- Deformity
- Decompression
- Grafting
- Fusion
- Revision
- Instrumentation

The defining characteristics of each of the 10 Types of surgery are Detailed in Appendix A.
Data Mining

Prediction Models
- StS Times
- Time to Incision
- Closure to Exit
- Post Length of Stay

Calculation of Probabilities
Simulation

Scheduling Algorithm
- Evaluation and Simulation
- Implementation

Interaction with Practice
ROI Secondary To:

- **Cost reduction**
  - From 3 to 2 ORs
  - Fewer “no-hitters”
  - Decreased weekend stays of Medicare patients
  - Less use of ORs outside of prime time

- **Increased revenue**
  - More cases
  - Case mix
“I have always thought a good deal of Lincoln’s Gettysburg address. There’s a line in it which explains why we want to do this thing. It is ‘that these dead shall not have died in vain.’ We know how hard it is for those who have had the misfortune of deaths in their families, of deaths that might have been avoided. What better could we do than take young men and help them become proficient in the profession so as to prevent needless deaths?”

Original Charge from HPS

• To create a meaningful mechanism to review deaths at MCR hospitals:
  • Thorough understanding
  • Measurable
  • Improvable

• To identify and quantify unanticipated deaths
• To identify rate of adverse events in patients who die in MCR hospitals
• To classify and quantify system level changes which will improve mortality rate.
Aggregate learning

Is there anything that could mitigate future events?

Prioritization of information

Identification of issues

Raw Information

Yes

No

No further review

Further review

Problem

No problem

case reviews

Report

Clinical Practice

Quality

How the review process flows to completion
Multidisciplinary reviews identify multidisciplinary “issues” with practice

- Ongoing culture shift with issue identification
- Long gone are the days of “nurses’ jobs” or “physicians’ responsibilities”
- Physician involvement
- Integral part of how business is done
  - Leadership involvement
  - Leadership accountability
Omission vs. Commission
Systems and Processes of Care (quantitative analysis, 2007)

• Most triage issues result in a FTR
  • RR 61.8 (95% CI 34 - 111)

• Primary causes of FTR and unanticipated death
  • Unrecognized septic and hypovolemic shock
  • Missed diagnosis

• Autopsy rate - 26%
  • cause of death determined by autopsy at least once per month
Making a Difference through 2009

P-chart of % of deaths with issues identified

- Nursing sepsis education
- Wipe C-diff initiative
- Sepsis order set
- Admission office
- Airway management protocol
- Other localized efforts: official reads on outside films, consultant notification of patient condition change, NGT suction and chest tube inservices, DOM encouragement of RRT utilization

Data source: MRS Mortality Registry
MRS System Findings (2010)

- Narcotic-induced respiratory depression
  - postoperative
  - OSA
- Failure-to-Rescue
- Failure-to-Recognize
  - Septic shock
  - Hypovolemic shock
  - Mesenteric ischemia
- Triage of unstable patients
- Supervision
Pareto Chart: All Issues 2012 vs 2013

2012 YTD MCR Inpatient Deaths with Issues
(Patient may be represented in the graph more than one time**)

This information is confidential and protected from disclosure by Minnesota Statute 145.61 et seq.
Case Example

55-year-old male with CLL with MUD peripheral blood stem cell transplant 7/10 (2 months before). Dismissed 9/14 Readmitted the following day for weakness, poor intake, diarrhea, depression.
During hospitalization: GVHD of the gut, CMV positive: AKI.
Graph starts at hospital day 14.

Labs:
Hb: 7.1
Creat (9/29): 3 (2-month baseline): 1.6
Leukocytes: 2.3

9/28 11am: Systolic BP in the 70-80s for 1 hour.
9/29 4am: Systolic BP 82, stayed erratic, mostly under 90 throughout the day. SI>1.
9/30 7am: RRT called

Example provided by MRS
Health Care Systems Engineering Approach to Process Discovery, Design & Implementation

Oversight Management Team

Requirements Team
- Identify and understand all stakeholder needs
- Classify and quantify user requirements
- Develop use cases

Analytics Team
- Identification of covariates predictive of deterioration
- Model pre and post intervention system performance

Systems Architecture Team
- Integrate stakeholder needs, results of analytics and operational use specifications
- Develop predictive algorithms and decision support
- Determine metrics

Clinical Verification & Validation Team
- Verification of outcome and process measures
- Statistical validation of predictive model
- Iterative sensitivity & specificity testing of predictive algorithms

Clinical Pilot Team
- Develop pilot
- Implement pilot
- Evaluate pilot
- Determine timing and sequence of scalable implementation and diffusion

Clinical Integration & Diffusion Team
- Develop implementation plan
- Develop ongoing measurement and monitoring plan
- Diffusion

Reengineering Phase
- Failure Modes and Effect Analysis, Data mining, Predictive analytics, Financial Effect Analyses
- Workflow analyses & Simulation Modeling

Implementation Phase
- Iterative DMAIC steps

Diffusion Phase
- Mayo Clinic Model of Diffusion
Top 5 Failure Modes (MCR)

• The patient's clinical condition is not re-assessed at the bedside following new interventions (medication, fluid bolus, tests results). This may result in a loss of important information with delayed recognition of needed intervention or treatment failure.

• Care providers of all types can feel that there are too many complex things to do in a short period of time. This may result in important care processes slipping through the cracks (including recognition that a patient's condition is changing).

• A physician does NOT review nursing notes documented in the electronic medical record. This may result in an incomplete understanding of patient clinical condition.

• Care team attributes a patient's acute physiological deterioration to the wrong cause. This may result in incorrect treatment choices and a delay in the appropriate care.

• Some care providers (nurses or physicians) believe that a standard, or clear definition of acute patient deterioration does NOT exist. This may result in uncertainty and variation amongst providers of how and when to respond to acute patient needs.
Next 5 Failure Modes (MCR)

• Care team fails to recognize subtle changes in vital sign trends over time. This may result in delayed recognition and interventions for a deteriorating patient.

• A physician, nurse practitioner or physician assistant uses 'copy and paste' to document in Clinical Notes from one day to the next. This may result in inaccurate representations of patient's current clinical condition.

• A patient's condition is continuing to deteriorate after several interventions. The nurses do not call the RRT because the primary service is at the bedside and ordering these interventions. This may result in a delay of care escalation.

• A physician is concerned about being judged as clinically weak, or incompetent, if the RRT is called for one of his/her patients. This may result in an under-utilization of the RRT expertise.

• A physician or nurse may NOT call the RRT, even when the patient is meeting calling criteria, because he/she believes the clinical calling thresholds are not relevant to their patient.
ROC Curves of Published Early Warning Scores and current MCR RRT criteria

ROC for rrt using varying coverage hours

- True Positive Rate (Sensitivity)
- False Positive Rate (1-Specificity)

Legend:
- RRT0
- RRT30
- GMNEWS
- MEWS
- SEWS
- VIEWWS
- WRTH
System Architecture Requirements:

• Tiered rescue model with time limited escalation of expertise with demonstrated clinical response
  • Bedside evaluations
  • Increased provider vigilance
  • RRT to be called when their specific expertise is needed
• Promotes teamwork and communication
• Makes the deterioration and results of interventions visibly obvious to bedside providers
• Allows all types of students, residents and fellows to learn
• Allows patient and family preferences to be incorporated into rescue response
• Makes practice constraints evident
• Leverages technology at the point of care (bedside)
“Guardian Angel” at the Bedside: Saving Lives
Tiered, time-limited escalation of expertise at the bedside

Validation

Tier 1
- First responder to bedside & notifies senior member of team

Tier 2
- Second responder to bedside for eval of clinical condition, differential, goals of care, and plan for reassessment

Tier 3
- ? RRT

Evaluate/treat/resolve or silence/snooze
Max 2-3 hours

Evaluate/treat/resolve or silence/snooze
Max 2-6 hours

RN clinical verification of vital signs

Concept derived from 6 RN focus groups & discussions with MERS, Sepsis MTR, CC-IMP & HIM quality committee including their practice leadership. MANY details to sort through as portion of Phase 2 BPR Charter. The practice must design the process and policies.
Clinical Engineering Learning Laboratories provide real-time practice and outcomes measurement to support interdisciplinary teams of engineers and health services researchers embedded into busy, live patient care environments.
Implementation
Analytics and IT in Health Care

- **Stage 5**
- **Stage 4**
- **Stage 3**
- **Stage 2**
- **Stage 1**

**MRS**

- Requires FDA approval
- BPR and Guardian Angel

ACTIVATING
MAKE it happen!

Event-based triggering takes hold
Patients need us to tell their stories. Clinicians need scientific evidence.

Hospitals need both… NOW: stories and analytics to learn, improve systems, advance care, and save lives.