High Reliability in Healthcare-
Stanford Medicine Center for
Improvement

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Newborn with left-sided pneumothorax
What do you see?
Today’s agenda

• What is HRO
  • High reliability- organizations, organizing, outcomes
  • How does it fit into the context of Patient Safety?
  • Background
  • Terminology and methodologies

• Experiences in other industries

• HRO in Healthcare
  • Various models
  • Examples
  • Challenges and opportunities

• The path forward
What is reliability?

The ability to perform required functions
How to prevent accidents from cascading into much larger failures?

- Bhopal - Anatomy of a Crisis - Paul Shrivastava (Methyl isocyanate release)
- Challenger crash
- Fukushima
- Tenerife
- Preventable healthcare deaths
- Automotive or aircraft crash with fatalities

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Lessons from other high-consequence industries

- NASA
- Commercial aviation
- Nuclear industry
- Firefighting
- Mining and gas
Challenges of adopting HRO in Healthcare

• Complexity of processes and systems (upcoming slides)
• Competing values- HIPAA, safety, efficiency
• Distraction, cognitive error, bias
• Struggling with the impact of “culture”
• How to make HRO concepts accessible to entire healthcare team
• How to actually improve outcomes
  • Implementation science
  • Contemporary approaches- Lean, Six Sigma, failure modes effects analysis (FMEA), socio-technical probabilistic risk assessment (ST-PRA), after action review (AAR), systems- theoretic accident model and processes (STAMP)
• What is the correct goal
  • 20% annual improvement (Similar to a Quality Improvement Project)?
  • Zero preventable harm?
  • As low as is reasonably practicable (ALARP)?
Definitions and principles

- Drucker’s perspective
- Gleick and Chaos theory
- Complex- "emergent behavior"
  - Increasing complexity is one of the main causes of failure
  - Lessons from engineering
- Complicated- predictable endpoint if steps are followed
  - With enough computing power, results can be accurately predicted
- Stochastic- patterns can be evaluated but not accurately predicted
- Project management
Safety in Complex Systems
High Reliability- in the context of patient safety

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The evolution of safety in complex systems
A perspective from MIT

• Perrow- Normal Accident
• High Reliability
• System Design


• Karen Marais, Nicolas Dulac, Nancy Leveson
High Reliability Theory- to consider

• Prevent the precipitating event from occurring- precursors
  • Can be extremely difficult to anticipate/preclude mistakes or mishaps
  • Robust system design
  • Education, on-boarding, careful screening prior to hiring

• **Prevent the error from cascading into a crisis- defenses**
  • Perrow, Shrivistava, and others
  • Different types
  • Functions
  • Shortcomings

• Culture is foundational (recurring theme in Patient Safety)

• A few themes from the science of “complexity”- to briefly consider today
FSORE

• Preoccupation with FAILURE
• Reluctance to SIMPLIFY
• Sensitivity to OPERATIONS
• Commitment to RESILIENCE
• Deference to EXPERTISE

Managing the Unexpected Weick and Sutcliffe
Different perspectives on HRO

• Institute for Healthcare Improvement (IHI)
• Agency for Research and Healthcare Quality (AHRQ)
• Clapper (HPI- Press Ganey)
• Marx and Westphal (Outcome Engenuity)
• MIT
What scares you the most?

“Werewolves!”
-Paul

What scares you the most?

“Sharks”
-Nina

What scares you the most?

“The unstoppable marching of time that is slowly guiding us all towards an inevitable death.”
-Dylan

What scares you the most?

-Dylan
-Catherine
Terminology

• Flaw- precipitating event, error, mishap, mistake, “soft signal”
• System failure- crisis, catastrophe, undesired outcome, harm event
• Defenses- exist between the ”flaw” and system failure
  • Barriers
  • Recover
  • Redundancy
• Precursor- prior to the flaw
• Mitigation- after the system failure

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“Defenses” - principles and examples

• Redundancy-
  • Principle - parallel systems components designed to independently prevent harm
  • Rock concert and festivals have multiple artists and/or multiple stages (Montreal 1992)
  • Setting two alarms the morning of an important final exam
  • RN confirming chemotherapy dose after pharmacists have confirmed

• Recovery-
  • Principle - catch flaw after it occurs but before causes harm
  • Holding a child’s hand before crossing the street - recovery
  • Going back and checking the front door to make sure that it’s locked

• Barrier-
  • Principle - physical component that prevents flaw (precipitating event) from cascading
  • Surgical mask and isolation rooms
  • Air bags and crumple zones in cars
  • Lawnmower’s deadman control

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Wrong kidney removed- August 13, 2016

- Roland Smith had large cancerous mass adjacent to right kidney
- Multiple radiology studies confirmed mass on right side
- July 12, radiologist report mass on left side
- July 27, urologist dictates note- left renal tumor
- Old records requested and MD “verified” records were reviewed
- Left side prepped
- Left kidney removed with Da Vinci robot
Wrong side marked in pre-operative area

• Precursors- mindfulness, controlling productivity pressures
• **Flaw**- patient arrives in operating room with wrong side marked
• Barrier-
  • Recovery- procedural pause, review images prior to incision
  • Redundancy- separate team comes into OR to confirm side
• **System failure**- operate on wrong side
• Mitigation- second surgery, transplant, etc...

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Billabong Odyssey

• https://www.youtube.com/watch?v=dhjP1c5agLU
Tow in surfing

• Precursors- training, equipment
• **Flaw- surfer falls on wave**
• Barrier- life vest
• Recovery- partner on jet ski
• Redundancy- second jet ski anchored away from waves
• **System Failure- drowning**
• Mitigation- hyperbaric treatment, ICU care, etc...
What makes a process “complex”

- Tight coupling - systems operated in close proximity
- Non-linear interactions (butterfly effect)
- Parallel vs. series processes
System complexity- additional principles

• Many components may **interact**
  • Human brain
  • Weather
  • Ecosystems, economics, organization, cities, etc...

• **Emergence** and emergent pattern formation
  • Egg placed in a box without heat- it degrades
  • Egg placed under heater- life emerges

• **Adaptive**

• **Feedback** loops

• **Dynamics**- e.g.- turbulent air flow

• [https://repository.upenn.edu/cgi/viewcontent.cgi?article=1133&context=asc_papers](https://repository.upenn.edu/cgi/viewcontent.cgi?article=1133&context=asc_papers)
• [https://www.eolss.net/sample-chapters/C05/E6-06B-02-05.pdf](https://www.eolss.net/sample-chapters/C05/E6-06B-02-05.pdf)
• [https://www.youtube.com/watch?v=9KA6PWim2TA](https://www.youtube.com/watch?v=9KA6PWim2TA)
Santa Barbara boat fire - MV Conception

• Facts
  • Sept 2, 2019
  • Night dive
  • Plugged into chargers - flashlights, cell phones, underwater camera batteries
  • Fire consumed the boat
  • 33 passengers and one crew member died

• Investigation

• HRO principles - include
  • tight coupling, complex interactions, no parallel safety system
  • Also - recovery, redundancy, barriers, precursors, mitigation

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Coupling- tight or loose

• Concept- system operate in close proximity (temporally or physically)
• Principle- tight coupling is more prone to failure
• Examples
  • MV Conception and location of electrical outlet
  • Why airlines maintenance crews must check coffee maker before flights
  • Setting multiple alarm clocks for the morning of the final exam
    • Put the alarm clocks far apart around your room
    • Multiple alarms on your phone- what if power failure and your phone has no charge?
Linear and non-linear

• Linear- sum of its original parts
• Non-linear- the whole is not a mere collection of the individual parts
• Examples of non-linear interactions
  • immune interactions
  • epidemics
  • social interactions
  • ecosystems
  • inter and intra-species dynamics
Parallel vs series

• Series- if any component fails, the system fails
  • Reliability of the system is always < than reliability of any individual component
  • i.e.- system failure rate > than failure rate of weakest link
  • E.g.- parts of a bicycle- chain, front wheel, back wheel, etc..

• Parallel- system only fails if the entire system fails
  • Probability of failure-free operation is always greater than probability of most reliable element of the system
  • E.g.- twin engine plane (let’s talk about single engine operation- Vmc)
  • Four-cylinder engine- can theoretically function if any cylinder is operating
  • E.g.- redundant and separate cooling systems for nuclear reactor core
  • Be careful about “hidden” dependencies so not truly parallel (more later)

https://www.intechopen.com/chapters/50094
https://web.cortland.edu/matresearch/SeriesIParallelSTART.pdf- just for fun
Catastrophic failure—common factors across industries

• Complex systems/operations
• “blame the victim” mentality
• High productivity pressure
Fractals- appear the same at different scales
Failure rates in multi-step series processes

• If 99% reliability for each step in a 50-step process
  • Failure rate is 40%
  • Failure rate is much higher than 40% if:
    • Complex (non-linear interactions) between any of the steps
    • Tight coupling in any element of the system
    • Any dependency in the system- next slide
To consider:

- Error dependency
- Behavioral dependency
- Common cause failure

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Pandemic example

• Precursors- education, regular contact with employees, home testing
• **System Flaw**- employee shows up to hospital with symptoms
• Barrier- mask
• Recovery- screening temperature and Covid history at entrance
• Redundancy- two separate screeners- ask questions and take temp
• **System Failure**- employee exposes an immunocompromised patient
• Mitigation- Regen-Cov, anti-pyretics, ICU, ventilator, pressors, etc...

Example-
NICU RN attempts to attach milk feeding to i.v. line

• Precursors- training, proctoring
• **Flaw-** RN at bedside thinking he is starting a feed
• Barrier- non-compatible connector
• Recovery- follow line to the patient
• Redundancy- two RN’s confirm prior to infusion
• **System failure-** infusing milk into a central line
• Mitigation- fluids, blood pressure support, etc...
Driving a car on a single-lane road with no median

- Precursors- take a different route
- **Flaw-** driver drifts into opposing traffic
- Barrier-
  - Recovery- rumble strip (drunk bumps), self-correcting car
- Redundancy-
  - **System failure-** collision
- Mitigation- crumple zones, air bags, emergency response
Surgeon accidently severs a blood vessel

- Precursors- training, proctoring
- **Flaw-** surgeon’s scalpel slips 1 millimeter
- Barrier-
- Recovery-
- Redundancy-
- **System failure-** severed blood vessel
- Mitigation- repair, vascular consult, fluids, etc...

- WHAT DO YOU NOTICE?
What do we do with this information?

• Consider multi-step processes and potential failure points
  • Cervical cancer screening, PSA’s, outpatient hypertension management
  • Ordering a complete blood count (CBC) on a patient in the ICU
  • Correctly delivering a food tray to a patient on telemetry

• Accept that
  • Systems can be unstable and unsafe
  • Resources are limited
  • Competing values are present (safety in one of many values)
  • Culture is foundational

• Next Steps- consistent with institutional goals of:
  • Research- funding IHI, AHRQ, NIH, private foundations
  • Education- teach others the Stanford approach to system safety
  • Clinical excellence
Looking forward

• The role of reliability engineers
• Patient Safety Course in Biomedical Engineering (multi-disciplinary)
• Supporting existing programs and initiatives, including
  • Stanford Medicine Center for Improvement (SMCI)- please join
  • Clinical effectiveness Leadership Training (CELT)
  • Realizing Improvement through Team Empowerment (RITE)
• Opportunities- Meaningful look at how systems are constructed
Long-term

• HRO as an integral component of Safety in Complex Systems
• Certificate Program and/or Master’s Degree in Patient Safety
• Disciplines and students-
  • Behavioral psychology
  • Engineering
  • Professional schools- medicine, nursing, pharmacy, etc...
  • Pre-health care
  • IT
  • Business school
  • Etc...
Thank you- bturbow1@Stanford.edu
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