System Theory-based Accident Analysis

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Accident Models

(Reason, 2000)

(Leveson, 2011)

(Vincent C, 2000)

(Rasmussen, 2000)
Swiss Chess Model

(Reason, 2000)
Bowtie Analysis

(Hollnagel, 2008)
Model of Organisational Accidents

(Vincent, 2000)
Human Factors Analysis and Classification System (HFACS)

http://www.skybrary.aero/index.php/Human_Factors_Analysis_and_Classification_System_(HFACS)
Socio-Technical System Model

(Rasmussen, 2000)
AcciMap

Clostridium Difficile Infection
Systems Theoretic Accident Model and Processes (STAMP)

Controller

Mental Model

Controlled Process

Control Actions

Feedback

Inadequate

(Leveson, 2011)
Causal Analysis based on STAMP

(Leveson, 2011)
System Theory

- Developed in the 1940s and 1950s to understand the behaviour of complex systems in biology and in engineering
- Self-regulating systems (self-correcting through feedback)
How is STAMP different?

- Accidents are more than a chain of events
- Treat accidents as a control problem
- Prevent accidents by enforcing constraints on component behaviour and interactions

(Controller, Controlled Process, Mental Model)

(Leveson, 2011)
A train driver was **distracted** and **misread** signal.
Control Structure

- Recruitment
- Selection
- Training
- Medical screening
- Working hours regulation
- Day-to-day manpower planning

- Signalling
- Rail tracks
- Train scheduling
- Procedures
- Regulations

Train Driving

Competency and fit-to-work  Operation
Systems theoretic accident analysis

- Goal is to identify the **flaws in the system control structure** that contributed to the Adverse Event to determine how to redesign the safety control structure to be more effective

(Leveson, 2011)
Draw the control structure

- High-level

(Federal Aviation Administration)

(Air Traffic Control)

(Leveson, 2011)
Generic Safety Control Structure

System Purchasing
Staff Recruitment
Staff Training
Quality Improvement
Risk Management
Change Management

(System Development)

Congress and Legislatures
Legislation
Government Reports
Lobbying
Meetings
Government Regulatory Agencies
Insurance Companies, Courts

(System Operations)

Congress and Legislatures
Legislation
Government Reports
Lobbying
Hearings and open meetings
Accidents

Government Regulatory Agencies
Insurance Companies, Courts

Regulations
Standards
Certification
Legal penalties
Case Law

Company Management

Safety Policy Standards Resources

Company Management

Operations Management

Operations Reports

Operating Process

Human Controller(s)

Automated Controller

Actuator(s)

Sensor(s)

Physical Process

Problem Reports
Incidents
Change Requests
Performance Audits

(Léveson, 2011)
Mental Model

Human Controller

- Safety-related responsibilities
- Inconsistent Mental Model

Controlled Process

- Undesirable /unexpected Environmental Inputs
- Missing or incorrect Feedback
- Inadequate Control Actions

(Leveson, 2011)
Four Types of Inadequate Control Actions

1. **Not** Given
2. Given, but **Unsafe**
3. **Too early, too late** (Timing)
4. Stop **too soon** or applied **too long** (Duration)

(Leveson, 2011)
Generic Safety Control Structure

(System Operations)

Congress and Legislatures
- Legislation
  - Government Reports
  - Lobbying
  - Hearings and open meetings
  - Accidents

Government Regulatory Agencies
- Industry Associations, User Associations, Unions, Insurance Companies, Courts
- Regulations
- Standards
- Certification
- Legal penalties
- Case Law
- Accident and incident reports
- Operations reports
- Maintenance Reports
- Change reports
- Whistleblowers

Company Management
- Safety Policy
- Standards
- Resources
- Operations Reports

Operations Management
- Work Instructions
- Change requests
- Audit reports
- Problem reports

Operating Process
- Human Controller(s)
- Automated Controller
- Actuator(s)
- Sensor(s)
- Physical Process

Revised operating procedures
- Software revisions
- Hardware replacements

Problem Reports
- Incidents
- Change Requests
- Performance Audits

(Leveson, 2011)
CAST (Causal Analysis based on STAMP)

1. Identify system hazard violated and the system safety design constraints

2. Construct the safety control structure as it was designed to work
   - Component responsibilities (requirements)
   - Control actions and feedback loops

3. For each component, determine if it fulfilled its responsibilities or provided inadequate control.
   - Context
   - Process Model Flaws

(Leveson, 2011)
CAST (2)

4. Examine coordination and communication
5. Consider dynamics and migration to higher risk
6. Determine the changes that could eliminate the inadequate control (lack of enforcement of system safety constraints) in the future
7. Generate recommendations

(Leveson, 2011)
The patient had been admitted to the cardiac care unit (CCU) where he was being supported with a left ventricular assist device to bridge to transplant. When a heart became available, the patient was taken to the operating room, and an uncomplicated cardiac transplantation was completed. Shortly after surgery, the patient showed worsening left ventricular function. The patient was placed on extracorporeal membrane oxygenation and treated for presumed transplant rejection. Careful analysis of the patient's chart revealed that immunosuppression had been ordered but never given preoperatively.
1. Identify system hazard violated and the system safety design constraints

<table>
<thead>
<tr>
<th>Hazard</th>
<th>Safety Constraint</th>
<th>Safety Constraint Violated</th>
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<tbody>
<tr>
<td>?</td>
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Hazard: Conditions or events that can lead to an accident

(Leveson, 2016)
1. Identify system hazard violated and the system safety design constraints

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<td>Patient unprepared for operation</td>
<td>Surgical checklist (Timeout)</td>
<td>Preoperative medication was not administered</td>
</tr>
</tbody>
</table>

Hazard: Conditions or events that can lead to an accident

(Leveson, 2016)
2. Safety control structure

Human Controller

- Safety-related responsibilities
- Mental Model

Control Actions ➔ Feedback

Controlled Process

(Leveson, 2016)
3. For each component, determine if it fulfilled its responsibilities or provided inadequate control.

<table>
<thead>
<tr>
<th>Loop</th>
<th>Safety responsibilities</th>
<th>Inadequate control action</th>
<th>Context in which decisions made</th>
<th>Process or mental model flaws</th>
</tr>
</thead>
</table>
| 1  
( CCU RN) | Administer preoperative medications | Did not administer preoperative immunosuppression | New leadership in cardiac surgery pushing cardiac transplant further | Not aware that they needed to give the immunosuppression |
|      | Report concerns about patient to the surgical team | Did not tell surgical team | The order in the EHR does not specify who is responsible for carrying out the order | Not aware that they needed to give the immunosuppression |
|      |                                         |                          |                                 |                             |

(Leveson, 2016)
4. Examine coordination and communication

- CCU RN assumed preoperative medication was administered
  - No feedback was provided
  - Feedback was inadequate (incorrect, ambiguous or missing)

(Leveson, 2016)
2. Safety control structure

OR Management
- Ensure medications available
- Ensure proper medication procedures
- Oversee timeout procedures to ensure used and effective
- Investigate adverse events

Procedures (timeout, medication)
- Performance audits
- Adverse Events
- Other Reports

Attending Cardiac Surgeon
- Order preoperative antibiotics and immunosuppressant
- Ensure patient ready for surgery before beginning
- Execute Timeout

Process Model
- Appropriate meds ordered? (yes/no)
- Ordered meds given? (yes/no)

Execution of timeout
- Check EHR
- Timeout responses
- Timeout response

Surgery Fellow/First Assist
- Order preoperative antibiotics and immunosuppressant
- Ensure medications have been given

Process Model
- Appropriate meds ordered? (yes/no)
- Ordered meds given? (yes/no)

ICU Management
- Establish medication procedures
- Oversee implementation of procedures
- Investigate adverse events involving medication errors

Nursing Supervisors
- Ensure medication procedures and handoffs are being executed appropriately
- Identify necessary improvements in procedures

Nursing Assignments
- Observation

SICU/CCU RN (pre-op)
- Administer pre-op meds

Process Model
- Ordered meds given? (yes/no)

Circulating RN
- Final check patient ready for surgery

Process Model
- Ordered meds given? (yes/no)

1. Pre-op meds
2. ID and other info check
3. Info about patient readiness (via EHR and Handoff)
4. Ready to start? (timeout)
5. Patient readiness (via Timeout)
6. Performance audits
7. Medication order (via EHR)
8. Performance audits Reports Adverse events

(Leveson, 2016)
5. Consider dynamics and migration to higher risk

Loop 6

- OR team order all preoperative medications and testing the night before

Loop 5

- EHR has a poor layout in terms of giving clear orders from the physician to the nursing staff and providing feedback regarding the carrying out those orders

(Leveson, 2016)
6. Determine the changes that could eliminate the inadequate control in the future

- Clear feedback on **who is in charge of** which task (medication administration)
- **Formal structure for handoff communication** between CCU nurse and surgical team
- **Time-out should include a question specific to immunosuppression** (only antibiotic check in the existing Time-out)

(Leveson, 2016)
7. Generate recommendations

- **Redesign of EHR interface** to provide clear feedback regarding the status of the medication ordered and carried out and who is responsible for what task

- **Tailor the checklist** to make it more specific to cardiac surgery rather than using one that is designed to be useful in every operation

- **Better change management procedure** – Risk assessment in place before any change

(Leveson, 2016)
Any thought on STAMP?
References

- Vincent, C. et al, 2000, How to investigate and analyse clinical incidents: Clinical Risk Unit and Association of Litigation and Risk Management protocol, BMJ 320 (7237)
- Reason, J. 2000, Human error: models and management, BMJ 320 (7237)
- Rasmussen, J. et al, 2000, Proactive Risk Management in a Dynamic Society, Karlstad, Sweden
- Leveson, N., 2016, A systems Approach to Analyzing and Preventing Hospital Adverse Events, J Patient Safety
Class Exercise
Insulin Overdose Case

1. On 15th of November Patient CS, a 70 year old female who resides in care home with mild dementia, was admitted to an acute medical ward with an intracranial bleed due to a fall. She presented with altered neurology and impaired cognitive function. The intracranial bleed was treated conservatively with a 5 day course of IV steroids.

2. On the 19th of November the patient was identified as having raised blood sugars and was reviewed by a Diabetes Specialist Nurse (DSN) who recommended starting insulin Glargine (a long acting insulin) 10 units daily. This was verbally handed over to the Dr on call and the ward nurse. The DSN documented her recommendations on the Diabetes team pink diabetics form and this was inserted into the main body of the notes. The notes entry stated

   “Commence Glargine U100 10units OD”.

4. The Dr prescribed 100 units Glargine once a day. This dose was administered to the patient on the 19th and 20th of November. Patient CS was transferred to a rehabilitation ward ready for discharge. The TTO (To Take Out) was written as “Glargine 100 units OD”.

5. On the 21st of November the patient was transferred to the Evington Centre (general rehab ward) and 100 units of glargine was administered on arrival. 100 units was administered on the 22nd and 23rd of November. The patients' blood sugars were noted to be low and the patient was readmitted to Emergency Department on the 24th of November with hypoglycaemia.

6. The patient was treated with IV Fluids until the 25th of January when the blood sugars stabilised.
Identify system hazard violated and the system safety design constraints

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Hazard: Conditions or events that can lead to an accident
Document the safety control structure

**Hospital Management**
- Ensure good information transfer at various interfaces
  - Forms, DB
  - Performance audits
  - Adverse events

**Ward**

**Diabetes Specialist Nurse**
- Recommend medicine
  - Mental model
  - Recommendation (verbal, pink form)

**Doctor**
- Check DSN’s recommendation
- Prescribe medicine
  - Mental model
  - Update of clinical status
  - Prescription
  - Clinical status
  - Inc. blood sugar level

**Ward Nurse**
- Monitor pt’s condition
- Administer medicine
  - Mental model
  - Medicine inc. insulin
  - Clinical status inc. blood sugar level

**Diabetic Patient**
- Admitted from care home
- Mild depression
- Impaired cognitive function
- Discharged to mental health trust

**Pharmacy**
- Ensure that prescription is correct
- Dispense medicine
  - Mental model
  - Prescription
  - TTO
  - Inc. insulin

**Discharge manager**
- Ensure that information is transferred
  - Mental model
  - Discharge summary
  - TTO, Prescription

**Mental health trust**