Workflow design and errors. An anesthesiologist’s perspective.

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Objectives

• Understand anesthesiology and see the parallels to radiation oncology and radiology
• See examples of system modeling methodologies
• Learn basic human factors concepts
• Understand that context matters.
  – How we use our equipment impacts safety

Anesthesia for the Non-Anesthesiologist
Anesthesia Related Mortality

In 1954, 1 in 1560 anesthetics led to patient deaths\(^1\)

In 2006, \(~0.7\) in 100,000 anesthetics resulted in patient deaths\(^2\)

Patient Safety in Anesthesia

AKA “How did we make anesthesia \(~100\) times safer in 50 years?”

- New medications with larger therapeutic indexes and more favorable side effect profiles
- Improvements in technology for sensors and drug delivery
- Thoughtful integration of new technology into anesthetic delivery workflows
What is Safety?

• Safety – state of being free from harm
• Emergent system property
  – Safety is not inherent solely to any device or person
  – Arises from the interactions of the components in your system

Workflow For Delivering Anesthesia

Bring Patient into OR
Apply standard monitors and obtain IV access
Deliver oxygen to patient
Secure patient airway
Induce anesthesia
Transport to Post-Op Recovery
Handover patient care
Awaken patient
Maintain anesthesia during surgery

More Detailed Process Map

Set up breathing circuit
Select gas mix and turn on gas flows
Pre-oxygenate patient
Select and start maintenance anesthetic
Select ventilator mode and start ventilating
Select airway management device and secure airway
Select agent and induce anesthesia

Yes

No

Ready for induction?
More Detailed Process Map

Failure Modes Effects Analysis

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Hypoxic Gas Mixtures

- Refers to any gas mixture that is less than 21% oxygen (25% in some machines)\(^5\)
- Two major ways that this can occur:
  1. The anesthesiologist accidentally sets the machine to deliver a hypoxic gas mixture
     - i.e. turning on the nitrous oxide instead of the oxygen
  2. The machine is set properly but is not delivering what was set

Gas Flow in Anesthesia Machine

Medical gases (i.e. oxygen, nitrous oxide, air) are piped into the operating room or held in tanks in the operating room

Pipelines and/or tanks are connected to the anesthesia machine

Valve decreases the gas pressures as they go from the high pressure to the low pressure circuit

Gases pass through a flow meter to the patient circuit in the settings established by the anesthesiologist
Gas Input Safety Mechanisms

- Pipeline gases use a diameter-indexed safety system
- Gas tanks use a pin-indexed safety system
- These measures ensure that the gas going into the flow meters is what the machine and the anesthesiologist expect

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Flow Meter Leak Fail-safe Design

The order of the gases entering the circuit is designed to prevent hypoxia in the event of a leak between flow meters
How do we now prevent anesthesiologists from turning the wrong knob and giving the wrong gas mixtures?

Human Factors Safety Measures

**Dual encoding:** using two or more methods to communicate information

Geographic Mapping to Display

Text Labels

Standardized Color Coding

Tactile Differences

Standardized Oxygen Placement
Interlock – Safety Measure

Oxygen/Nitrous Oxide Ratio Controller

• Physical or pneumatic interlock between the nitrous oxide and the oxygen flow meters
• Limits the ratio of the two to 25%

This safety feature came from an understanding of the device’s use in real-life workflows and environments

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Credit to The Far Side and Gary Larson
Systems Theoretic Process Analysis

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Alarm Fatigue

Too many alarms lead to people ignoring alarms and potentially dangerous situations

Graded Alarms

• Alarm information is coded in multiple ways:
  – Alphanumeric data
  – Color coding
  – Differential auditory alarms

• Machines grade alarms by the severity of the problem
  – Circuit Leak: low severity
  – Low Minute Ventilation: medium severity
  – Apnea: high severity
Adjustable Alarms

• Not all patients have the same physiology
  – Pediatrics vs young healthy adults vs chronically ill geriatric patients
• Therefore, alarm limits are adjustable, so you only see alarms that are pertinent to your patient

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Take Home Points

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