Using CAST for Adverse Event Investigation in Hospitals

Meaghan O’Neil
March 27, 2014
Motivation

“As many as 98,000 people, die in hospitals each year as a result of medical errors that could have been prevented”

To Err is Human
Institute of Medicine Report 1999
Overview

• Motivation
• Current Incident Investigation in Healthcare
• VA Collaboration
  – Case Study
  – Current RC approach
  – CAST analysis
  – Ongoing/Additional Work
## Introduction to System Safety Analysis

<table>
<thead>
<tr>
<th>Root Cause</th>
<th>CAST</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Based on chain of events model</td>
<td>• Based on System Engineering</td>
</tr>
<tr>
<td>• Identifies a limited number of “root causes”</td>
<td>• Design for complex systems (Recognizes emergent properties)</td>
</tr>
<tr>
<td>• Recommended by Joint Commission based on NASA engineering approach</td>
<td>• Identifies a larger set of causes</td>
</tr>
<tr>
<td>• Basis of Incident Reporting Tools used by the FDA, Joint Commission, Patient Safety Organizations</td>
<td>• Hardware component failures, component interactions, human and software interactions, systemic accidents (i.e. mode confusion) etc.</td>
</tr>
<tr>
<td></td>
<td>• Treats safety as a dynamic control problem</td>
</tr>
</tbody>
</table>

Traditional RC approach became mainstream after “To Err is Human”

**Necessary for complex systems**
Overview

• Motivation
• Current Incident Investigation in Healthcare
• VA Collaboration
  – VA Overview/Case Study
  – Accident Description
  – Root Causes Approach
  – CAST Analysis
  – Ongoing/Additional Work
VA Incident Investigation Process

- In-house Root Cause method (developed by NASA engineer)
- Patient Safety Officers Network with National Center for Patient Safety
- Process Driven
- Evaluation & Feedback reviews on RC and Action Plans
- Accredited by the Joint Commission
VA Collaboration - Case Study

- CAST applied to a Sample Accident (used for RC training)

**NOTE:** This teaching case has elements from many real case studies, but many details were manufactured to provide enough information to accomplish the RCA Team exercise.
Overview

• Motivation
• Current Incident Investigation in Healthcare
• VA Collaboration
  – VA Overview/Case Study
  – Accident Description
  – Root Causes Approach
  – CAST Analysis
  – Ongoing/Additional Work
Accident Overview

Diagnosis

Solitary Pulmonary nodule in upper lobe of right lung

Biopsy Procedure

CT scan guided fine needle biopsy of the lung nodule

10% Pneumothorax

Post Procedure Recovery

1 day Observation in Short Stay Unit (SSU)

50% Pneumothorax
Chest Tube Placed
4 day recovery
Patient

Patient presented with symptoms

Primary Care Nurse & Physician

Physical Exam

Suspected Diagnosis: Pneumonia

Diagnostics Ordered (Chest X-ray)

Informed Patient of Treatment Details

X-ray Tech & Radiologist

Solitary pulmonary nodule in upper lobe of right lung

X-ray Performed and Analyzed

Pulmonary Specialist

Treatment Order: CT Guided Lung Biopsy

Hospital Admin

Procedure to be performed Short Stay Unit (SSU)

Scheduled Procedure

Diagnosis

Biopsy Procedure

Post Procedure Recovery
Accident Chronology: Biopsy Procedure

**SSU Nurse**
- Initial Patient Prep

**Charge Nurse**
- Manage Overall Schedule Confirms Start
- Transport and Prep Patient and Procedure Room

**Procedure Nurse**
- Provides Direction for Procedure Prep
- Position Patient Perform Initial CT scan
- Plan and Perform Procedure
- Post Procedure CT Scan (10% Pneumo)
- Transports Patient to SSU

**CT Technician**
- Transports Patient to SSU

**Interventional Radiologist**
- Biopsy Procedure
- Post Procedure Recovery

**Resident**
- Post Procedure Recovery
Accident Chronology: Recovery

Procedure Nurse
- Transports Patient to SSU

SSU Nurse
- Connects Monitors
- Sees Patient in Distress, Reviews Chart
- Attempts to contact Radiology

Patient
- Silences Low Oxygen Alarm
- 15 mins

X-ray Tech & Radiologist
- Performed Chest X-ray 50% Pneumo
- 30 mins

Surgical Resident
- Places Chest Tube

Diagnosis
- Biopsy Procedure
- Post Procedure Recovery
Overview

• Motivation

• Current Incident Investigation in Healthcare

• VA Collaboration
  – VA Overview/Case Study
  – Accident Description
  – Root Causes Approach
  – CAST Analysis
  – Ongoing/Additional Work
Accident had occurred before

Corrective actions at that time included:

- **Awareness training** for residents on service;
- **Changed procedure** to have follow-up chest X-rays done within 2 hours, unless there was a change in status
VA Root Cause Analysis

Contributing Factors:
• The **complication was not disclosed** to the patient or treatment team
• **No hand-off** of the patient from Radiology to the SSU
• **Delay** in patient assessment
• **Patient is managing** his own **alarm**- **alarm safety issues**
• **This nurse is practicing out of her scope of practice** if she is an RN. She should have called the Resident/physician responsible for the care of this patient.

Root Causes: **There was a lack of communication** to the patient and treatment team regarding the complication which occurred in Radiology. This combined with the delay in **patient assessment** post procedure and the **patient silencing his own alarm** eliminated the opportunity to detect the pneumothorax in a timely manner.
Strongest Actions Proposed

• Lock out pulse oximeter so patient cannot manage controls
• Face to face hand offs with check lists
• Practice Issues
  – Addressed by peer review and addressed by supervisor
Overview

• Motivation
• Current Incident Investigation in Healthcare
• VA Collaboration
  – VA Overview/Case Study
  – Accident Description
  – Root Causes Approach
  – CAST Analysis
  – Ongoing/Additional Work
Accident Description

**Accident:**
(General) Patient harmed as a result of hospital care
(Specific) Patient’s lung is harmed while in the hospital for a procedure to biopsy a lung nodule

**System Hazards (related to this accident):**
- H1 Procedure damages sensitive tissue
- H2 Patient is unable to fully recover from procedure

**The System Safety Constraints (related to this accident):**
- Lung nodule must be biopsied without harming the patient
- The patient must be monitored and treated appropriately while recovering from the procedure
Physical System
Physical System

- Safety Requirements and Constraints Violated
- Failures and Inadequate Controls
- Physical Contextual Factors
Safety Requirements/Constraints Violated

- Provide imaging to aid in maintaining a safe pathway to nodule
- Obtain sample without harming patient

Failures and Inadequate Controls

- 10% Pneumothorax resulted from biopsy procedure
- Non quantitative method for assessing extent of pneumothorax
- Patient movement is not prevented or monitored

Physical Contextual Factors

- Inadequate imaging provides only intermittent partial views of the safe pathway, need to minimize harm from continuous imaging
- Post CT scan is used to view complications, X-ray used in follow-up

Safety Requirements/Constraints Violated

- Communicate patient status, actions performed, and procedure complications to all healthcare providers involved in patient’s care

Failures and Inadequate Controls

- Illegible writing in physical chart could resulted in lack of procedure details and complications available to SSU nurse and surgical resident
- Delay in transcriptions available in EMR

Physical Contextual Factors

- Physical Patient Files used are populated real time by hand believed to be fastest form of communication. EMR used as long term record, billing
- Staffing/time pressures as well as stress can affect the quality and readability of the information in the chart

Safety Requirements/Constraints Violated

- Provide continuous monitoring of patient status post procedure

Failures and Inadequate Controls

- Did not provide timely physical examination of patient
- Did not provide awareness of patient distress

Physical Contextual Factors

- Multiple patients are assigned to each nurse in the SSU
- Close proximity and open floor plan assumes nurses will be aware of patients in distress or worsening condition and gives patients the impression that they are continuously monitored
- Newly opened facility
CT/Fluoroscopy Guided Biopsy

Safety Requirements/Constraints Violated
• Imaging aid maintaining safe pathway
• Obtain sample without harm

Failures and Inadequate Controls
• 10% Pneumothorax resulted
• Non quantitative method for assessing harm
• Patient movement not prevented or monitored

Physical Contextual Factors
• Inadequate imaging provides only intermittent partial views of the safe pathway, need to minimize harm from continuous imaging
• Post CT scan is used to view complications, X-ray used in follow-up
Patient Record

Safety Requirements/Constraints Violated
• Communicate patient status, actions performed, complications

Failures and Inadequate Controls
• Illegible handwriting
• Transcriptions delay EMR record update

Physical Contextual Factors
• File populated real time by hand is fast/common approach, EMR used as long term record, billing
• Staffing/time pressures, stress can affect quality and readability
Short Stay Unit (SSU)

Safety Requirements/ Constraints Violated
• Continuous monitoring of patient

Failures and Inadequate Controls
• Lack of timely physical examination
• Patient distress unobserved

Physical Contextual Factors
• Patient to nurse ratio
• Close proximity and open floor plan assumes nurses will be aware of patients in distress or worsening condition and gives patients the impression that they are continuously monitored
• Newly opened facility
Control Structure Creation

Control Diagram created for each phase displayed in appendix
As Designed and Actual
Phase: Diagnosis
(Design)

Primary Care Physician

- Vitals, findings
- Presentation, history
- X-ray order
- Interpretation
- Image, interpretation

Primary Care Nurse

- Vitals
- Presentation, history
- Instructions for procedure

Equipment (monitors)

- Physiology
- Presentation, history

Equipment (X-ray)

- Position instruction
- Setting
- Image

Radiologist

- Interpretation
- Image

X-ray Tech

- Presentation, history, treatment consent

Pulmonary Specialist

- Diagnosis, treatment order
- Schedule availability

Scheduler/Admin

- Resource availability
- Availability, confirmation

Patient

- Anatomy
- History, treatment consent
- Presentation, history, treatment consent
Phase: Diagnosis
(Actual)

- Patient
  - Presentation, history
  - Vitals, findings
  - Instructions for procedure
- Primary Care Nurse
  - Vitals
  - Presentation, history
  - Physiology
- Equipment (monitors)
  - Instructions for procedure
  - Physiology
- Equipment (X-ray)
  - Setting
  - Image, interpretation
  - Anatomy
- X-ray Tech
  - Image
  - Position instruction
  - Diagnosis, treatment order
- Radiologist
  - Image
  - Interpretation
  - X-ray order
- Pulmonary Specialist
  - Image, interpretation
  - Diagnosis, treatment consent
- Primary Care Physician
  - Referral
  - Presentation, history
  - Vitals, findings
  - X-ray order
- Scheduler/Admin
  - Schedule availability
  - Availability, confirmation
  - Diagnosis, treatment order
  - Resource availability

Flow of information and actions:
- From patient to Primary Care Nurse:
  - Vitals, findings
  - Presentation, history
- From Primary Care Nurse to Equipment (monitors):
  - Instructions for procedure
  - Physiology
- From Equipment (monitors) to Equipment (X-ray):
  - Presentation, history
- From Equipment (X-ray) to X-ray Tech:
  - Setting
  - Image
- From X-ray Tech to Radiologist:
  - Image
  - Position instruction
- From Radiologist to Pulmonary Specialist:
  - Image, interpretation
- From Pulmonary Specialist to Primary Care Physician:
  - Diagnosis, treatment order
  - Referral
- From Primary Care Physician to Scheduler/Admin:
  - Schedule availability
  - Availability, confirmation
- From Scheduler/Admin to Pulmonary Specialist:
  - Diagnosis, treatment order
  - Resource availability
Phase: Recovery (Actual)

Interventional Radiology

Radiologist

Surgical Resident

X-ray Tech

Equipment (X-ray)

Equipment (monitors)

Patient

X-ray order

Image

Settings

Position

Anatomy

Alarm

Silence

Physiology

Vitals

Image Settings

Image

Vitals

Vitals

Verbal and physical presentation

Instructions

Clarification Request

Hand off

Stats, transport, approval

Direction

Procedure notes

X-ray order, procedure details

Status

Radiologist

Interpretation

Resident

Procedure Nurse

SSU Nurse
Controller Analysis

Controllers
• Safety Requirements and Constraints Violated
• Failures and Inadequate Controls
• Physical Contextual Factors

Case Limitations
• Standard Font – Details from case
• Italicics – Inferred based on observations from a Boston Teach Hospital
• Questions for further investigation noted
Controller Analysis (partial results)

Patient Safety Related Responsibility
• Provide accurate and complete information (physical and verbal clinical presentation)
• Provide consent and acknowledge understanding of the diagnosis, treatment plan as well as instructions for the procedure
• Follow instructions provided by Health Care Professionals

Unsafe Decisions and Control Action
• Patient may not have conveyed all relevant information to providers regarding pneumothorax risk factors
• Patient may not have remained still during the procedure
• Patient silenced the alarming oximeter during recovery in the SSU
• Patient may have been coughing or attempted to get out of bed while in the SSU

Process Model Flaw
• The patient most likely did not know what information was relevant for pneumothorax risk factors
• The patient may not have known he was at a high risk of pneumothorax
• The patient may not have understood the diagnosis or what pneumothorax was
• The patient may not have understood the requirements for the biopsy procedure
• The patient thought the pain he was experiencing was normal and not due to a complication
• The patient did not realize that he was in need of immediate medical attention

Context
• The patient likely had strong emotions at the time of this diagnosis (having just been told about the potential for lung cancer), which may have affected the patient’s ability to comprehend the procedure and its implications
• There may have been co-morbidities present which created a high risk of pneumothorax
• The patient may have had additional questions that he did not ask due to time pressure, embarrassment, or expectation that he should have known the answer
• The patient may have received previous treatment and therefore did not perceive a risk this time
• The information may have been given to the patient only verbally, making it difficult to remember and impossible to review after leaving the office
• The patient expected that he was being monitored
Controller Analysis (partial results)

Patient Safety Related Responsibility
• Follow instructions provided by Health Care Professionals

Unsafe Decisions and Control Action
• *May not have remained still*
• Silenced the alarm

Process Model Flaw
• Thought pain was normal
• Did not realize that he was in need of immediate medical attention

Context
• *May have had additional questions that he did not ask*
• *Expected nurse knew his condition*
Controller Analysis (partial results)

**Patient**

**Questions about the patient**

These questions were produced during the CAST analysis but were omitted from the case study report:

- Was all-relevant information conveyed to the providers that could have helped identify risk factors indicating that the patient was more susceptible to a pneumothorax?
- Was the patient at a high risk of pneumothorax due (for example, co-morbidities)
- What was the patients overall health state? Where there co-morbidities present?
- How much did the patient understand?
  - Did the patient have additional questions that he did not ask?
  - Did he feel time pressure?
  - Was he embarrassed to ask, feeling that he should understand what was being said?
  - Was there medical terms used, such as pneumothorax that he did not understand but did not ask for an explanation?
  - What was the patient’s level of education and comfort with English?
  - Was the patient under the influence of medication when instructions were given to him?
- What was the patient’s previous medical experiences
  - Had the patient received previous treatment and therefore did not perceive the risk in this procedure?
- What was the patients mental state of mind when the risk of the procedure and instructions where given?
  - It is very reasonable that the patient may have had strong emotions at the time, having been told he may have lung cancer. How did this affect the patient’s ability comprehend the information told to him?
- What instructions did the patient receive?
- Was the patient informed of the pneumothorax and symptoms to be aware of?
- How was information conveyed to the patient?
  - Was any of the information given to the patient in writing or only conveyed verbally? If verbal only, how accurately did the patient remember once leaving the office?
Controller Analysis (partial results)

**Patient**

**Sample questions**

- What instructions did the patient receive?
- Was the patient
  - Affected by sedation medication when instructions were given to him?
  - Informed of the pneumothorax and symptoms to be aware of?
Controller Analysis (partial results)

**Interventional Radiologist**

**Safety Related Responsibility**
- Determine the position of the patient in the CT scan based on the reported location of the nodule and the x-ray.
- Identify the size and location of the nodule from the CT scan image
- Select needle size for the procedure
- Predict/determine a “safe” pathway to the nodule to avoid harm to the patient when needed is traveling to the nodule
- Insert the needle into the patient’s chest along a safe pathway avoiding harm to lungs or other organs to the nodule, remove sample of nodule
- Retract the needle along a safe pathway avoiding harm
- Analyze the post CT scan to assess the patient for the existence of a pneumothorax following the procedure.
- Order a follow up x-ray to confirm the status of the pneumothorax
- Ensure the procedure notes are have been included in the patient chart and are included in the EMR system as well as complete the paperwork for the diagnostics lab, or assign the resident to complete these activities
- Teach the resident the biopsy procedure method while assessing the skillset of the resident

**Unsafe Decisions and Control Action**
- Allowed positive-pressure air to enter the negatively pressured pleural space, disrupting this natural vacuum
- Was not available or unable to speak with the recovery nurse
- Estimated the pneumothorax as 10% based on the CT scan

**Process Model Flaw**
- The Radiologists expects the safe path visualized on the CT scan image remains intact, as the needle is being inserted and removed. This pathway may have been compromised due to external or internal patient movement
- The Radiologist estimated the pneumothorax to be 10% in size based on the appearance of the 2D image available on the CT scan

**Context:**
- Pneumothorax occur ~40% of the fine needle biopsies performed, with 17% requiring chest tubes. The exact mechanism that results in the pneumothorax is not understood by the medical profession. It is not know in this case what caused of the pneumothorax.
- The fluoroscopy provides the clinician point in time image of the patient and the number of images taken must be minimized to avoid patient harm from radiation
- After the needle is inserted, the patient’s body may have moved (external movement). In addition, their lungs move as they are breathing (internal movement).
- May have been in a procedure and unable to be reached by the recovery nurse
- The sizing of the pneumothorax in the case is indicated as 10% initially. While a numeric value is assigned, the evaluation is not quantitative as one might assume and the appearance could be impacted by the patient’s position.
Controller Analysis (partial results)

Interventional Radiologist
Safety Related Responsibility
• Predict/determine a “safe” pathway
• Insert the needle along a safe pathway
• Ensure necessary details are in the chart

Unsafe Decisions and Control Action
• Punctured lung

Process Model Flaw
• Expected the safe path visualized to remain intact
• Estimated the pneumothorax to be 10%

Context:
• Pneumothorax occur ~40%, with ~17% requiring chest tubes
• Patient movement may have occurred
• 10% sizing
Controller Analysis (partial results)

**Interventional Radiologist**

**Sample questions**

- Could the pneumothorax have been larger than originally reported?
- Were there schedule or other pressures at the end of the procedure?
- Where there any interruptions or distractions during the procedure?
- Why was the radiologist not available to communicate with the SSU nurse?
Controller Analysis (partial results)

SSU Nurse

Safety Related Responsibility
- Participate in an effective patient handoff before and after the procedure with the procedure nurse including confirming information regarding the patient status and post procedure notes were received
- Set up the monitors when the patient arrives at the SSU
- Provide necessary instructions to the patient while in the SSU
- Monitor the patient’s status for signs of worsening condition
- Contact the Radiologist responsible for the care of the patient if required
- Ensure the Radiologists order for the follow up x-ray is performed as needed (to be done 2 hours after the procedure unless condition worsens)

Unsafe Decisions and Control Action
- Did not review the procedure notes in the patient chart until there was a sign that the patient was in distress
- Was unable to interpret the post procedure notes from the patient chart
- Did not appear to treat the patient as a high risk patient
- Did not check the patient status for 45 minutes after initially leaving the patient once the handoff and equipment set up was complete.

Process Model Flaw
- During the 45 minutes the patient was unattended, the SSU nurse believed that the patient’s status was normal

Context
- The SSU nurses are responsible for a multiple patients
- The nurse assumed that the oximeter would alarm if the patient had declining respiratory function
- The patient denied having any pain when he arrived
Controller Analysis (partial results)

SSU Nurse

Safety Related Responsibility
• Effective handoff with SSU nurse
• Instruct patient
• Monitor patient status

Unsafe Decisions and Control Action
• Did not review the procedure notes until patient was in distress
• Did not treat the patient as high risk
• Unaware of patient status for 45 minutes

Process Model Flaw
• Believed patient status was normal

Context
• Patient denied having any pain at handoff
• Assumed that the oximeter would alarm
Controller Analysis (partial results)

Questions about the SSU Nurse
These questions were produced during the CAST analysis but were omitted from the case study report:

• What was the environment of the SSU area that the day of the procedure?
• What was the hand off policy between the SSU area and the procedure nurse?
• What caused the nurse not to confirm the status of the patient for 45 minutes when the case states that patients are usually evaluated every 5 minutes?
• Why did the SSU nurse not hear the oximeter beeping? Did it sound only once before being completely silenced? Were there other nurses in the SSU area who heard the alarm or saw the patient appear to be in discomfort? If they did, did they take any action? If not, why not?
• Was the SSU nurse occupied with another patient or activities during the 45 minutes?
• Why was the nurse not able to reach the Interventional Radiologist? Why was the resident not called when the Radiologist was not available?
• Were there alterative actions that could have been taken to reduce the harm to the patient besides requesting a chest x-ray? Was the chest x-ray performed a mobile x-ray or did the patient have to be transported? How long did it take to get the x-ray and results?
• Did the nurse order the X-ray or did that order already exist?
• Who did the nurse contact when unable to reach the radiologist?
Controller Analysis (partial results)

SSU Nurse

Sample Questions

• Hand off policy?
• Why the 45 min delay?
• What were the details of the alarm?
• Why was the Radiology department unreachable?
CAST results (partial)

• A number of violated constraints should be addressed both for the physical system and the controllers

• Feedback throughout the system is lacking
  – Ensure a safe pathway to eliminate harm
  – Ensure communication is complete and understood
  – Adequately monitor condition for change
  – Improve the proactive measures to prevent decline
CAST Summary

• CAST provides a number of questions that can aid the patient safety officer investigating incidents

• Analysis uncovers more causal factors than the standard root cause analysis

• CAST allows for the identification of systemic hazards
Overview

• Motivation
• Current Incident Investigation in Healthcare
• VA Collaboration
  – VA Overview/Case Study
  – Accident Description
  – Root Causes Approach
  – CAST Analysis
  – Ongoing & Future Work
Ongoing & Future Work

• Complete CAST analysis will be available in masters thesis

Future Goals:
• Enable the application of CAST to “real” accidents
• Increase the use of STAMP throughout biomedical & healthcare community
Thank you
Appendix
Phase: Diagnosis
(Design)

- **Patient**
  - Presentation, history
  - Vitals, findings

- **Primary Care Nurse**
  - Presentation, history
  - Instructions for procedure
  - Physiology

- **Equipment (monitors)**
  - Vitals

- **Equipment (X-ray)**
  - Position instruction
  - Image
  - Anatomy

- **Radiologist**
  - Image, Interpretation

- **Primary Care Physician**
  - Referral
  - X-ray order

- **Pulmonary Specialist**
  - Diagnosis, Treatment plan

- **Scheduler/Admin**
  - Diagnosis, treatment order
  - Schedule availability

- **Image, Interpretation**
  - Setting

**Resource Availability**
Phase: Diagnosis (Actual)

Primary Care Physician

Primary Care Nurse

Equipment (monitors)

Equipment (X-ray)

X-ray Tech

Radiologist

Pulmonary Specialist

Scheduler/Admin

Patient

Presentation, history

Instructions for procedure

Vitals, findings

Vitals

Presentation, history

Position instruction

Setting

Image

Image, Interpretation

Diagnosis, Treatment order

Diagnosis, treatment order

Presentation, history, treatment consent

Setting

Image

Anatomy

Diagnosis, Treatment plan

Resource Availability

Availability, confirmation

Schedule availability

Diagnosis, treatment order

Presentation, history, treatment consent

Setting

Image

Anatomy

Diagnosis, Treatment plan

Resource Availability

Availability, confirmation

Schedule availability

Diagnosis, treatment order

Presentation, history, treatment consent

Setting

Image

Anatomy

Diagnosis, Treatment plan

Resource Availability

Availability, confirmation

Schedule availability

Diagnosis, treatment order

Presentation, history, treatment consent

Setting

Image

Anatomy

Diagnosis, Treatment plan
Phase: Biopsy Procedure (Actual)

Patient

Charge Nurse
- Approval
- Status
- Schedule Pressure

Procedure Nurse
- Trans. Request
- Status
- Physical Location, sedation, instructions
- Vitals
- Settings

Equipment (monitors)
- Physiology
- Status

SSU Nurse
- CT scan image
- CT scan order
- Post procedure X-ray order, procedure report

CT-Tech
- Anatomy
- Image
- Position
- Lesion position, Request for image
- Instruction, evaluation, pressure

CT
- Anatomy
- Image
- Position

Fluoroscopy
- Anatomy
- Position

Bed
- Position
- Piercing
- Anatomy

Equipment Needle

Interventional Radiologist

Resident
- Assistance, display of capacity
- Position
- Tactile Sensation

Interventional Radiologist
- Request
- Pressure
- Intention
- Approval Status

Phase: Biopsy Procedure (Actual)

- Sedation, position, equip orders
- CT - Tech
- Procedure Nurse
- Interventional Radiologist
- Resident
- Equipment Needle
- SSU Nurse
- Equipment (monitors)
- Charge Nurse

Patient
Phase: Recovery
(Design)
Interventional Radiology

Coaxial Biopsy Needle

Patient

Pre procedure CT scan
Needle
Fluoroscopy images

Needle Location (entry, angle, depth)
Pierces thoracic region (intended to follow “safe pathway”)

Controller

Visual, tactile feedback of needle location relative to the lesion and “safe pathway”
Patient

Internal movement (respiration)  
External Body movement

Lesion Location

Nurse or MD may witness body movement  
Or lesion may move out of the field of view on the fluoroscopy image

Nurse/MD Fluoroscopy images

Needle Location  
(entry, angle, depth)

Controller

Actuator

Pierces thoracic region (intended to follow “safe pathway”)

Lesion Location