# Analyzing Radiation Therapy Incidents

**Mohammad Bakhtiari, PhD, EMBA, DABR, CPPS,**
**CPHQ, CSSBB**

WellSpan Health, Chambersburg PA

# Radiation Therapy: Complex Interactions and High-Risk Dynamics

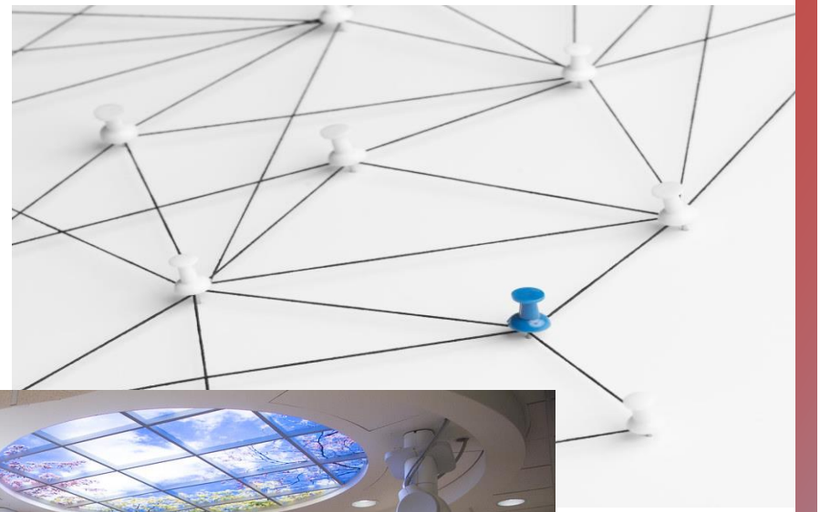
Radiation therapy uses targeted radiation to destroy cancer cells.

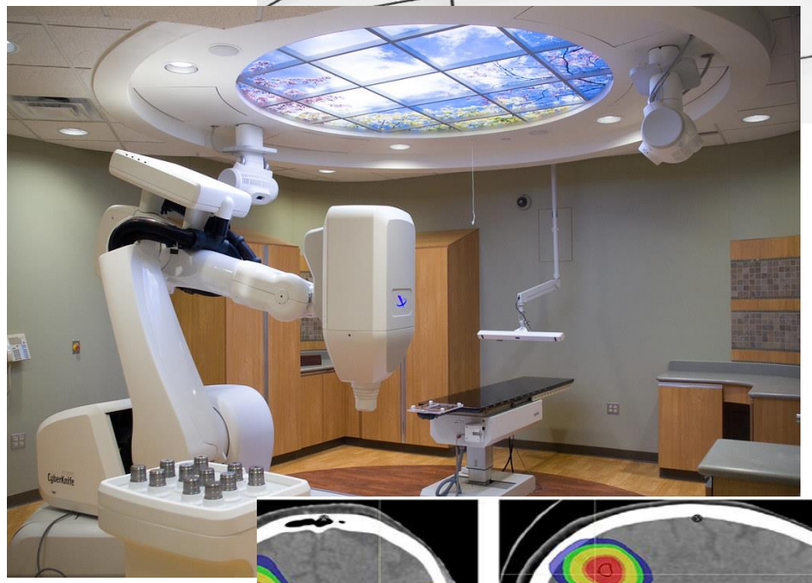
Treatment involves multiple interconnected agents, including clinicians, machines, and software.

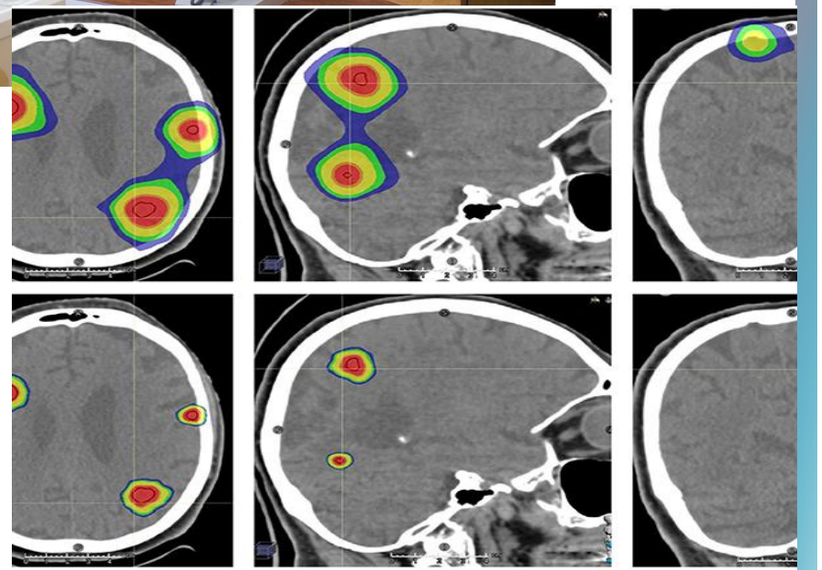
System complexity arises from the interplay between human, technical, and procedural factors.

High risk exists due to potential errors causing patient harm or treatment delays.

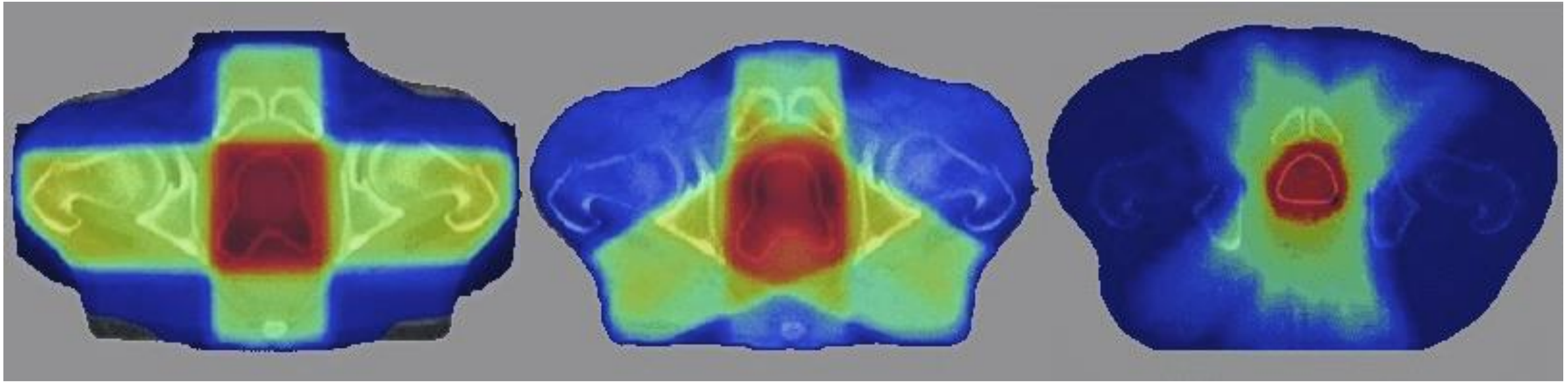
Understanding systemic interactions is essential for improving safety and outcomes.



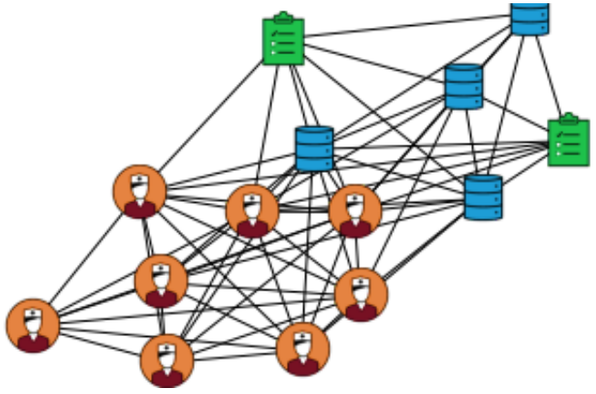




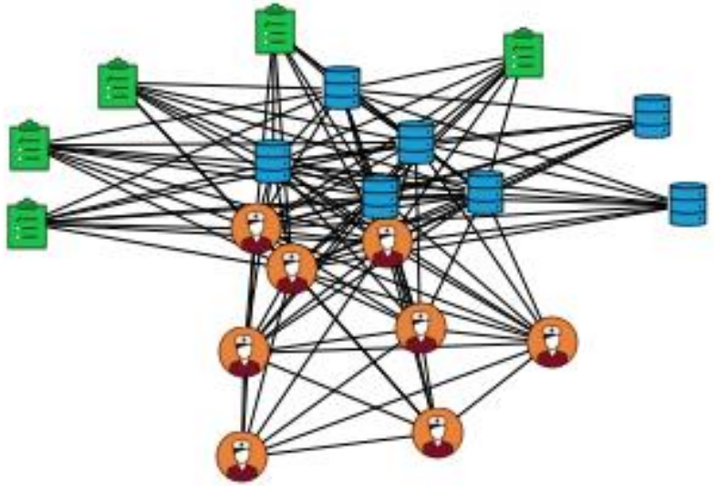
# Quality in the context of time and space



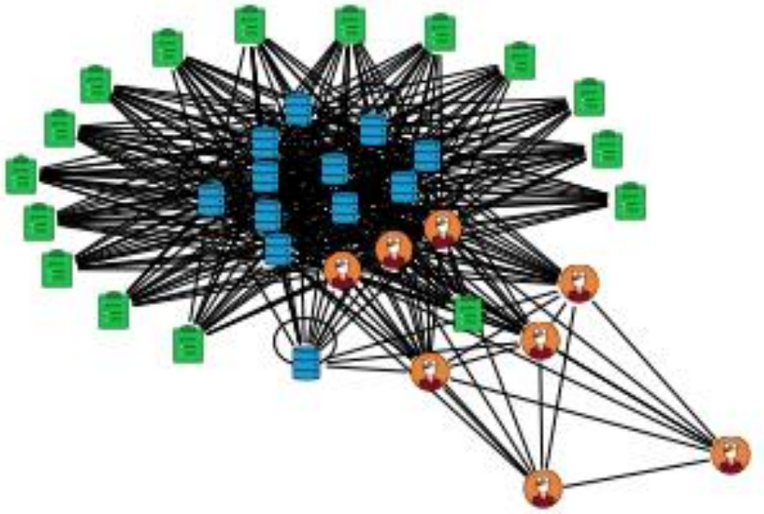
2000



2010



2020



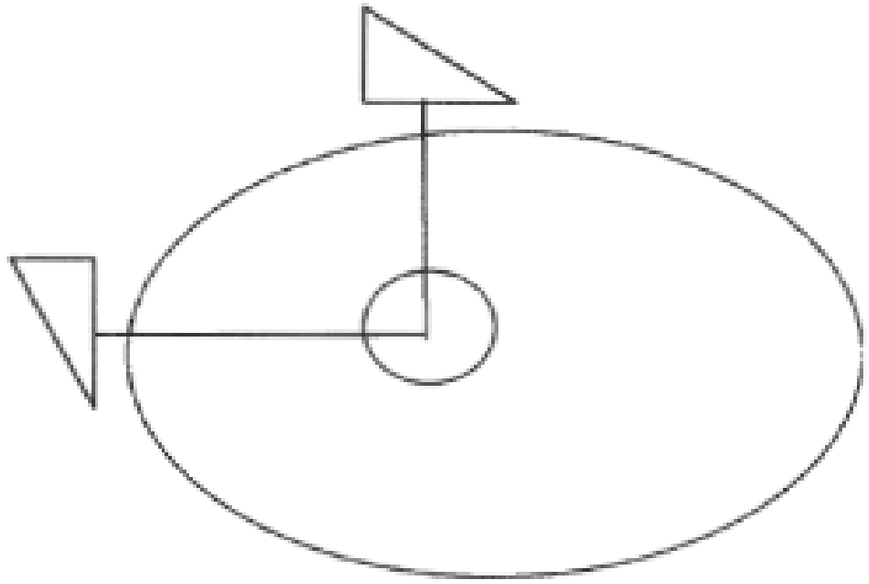
# Media-Penetrating Incidents: Biases and Recommendations

- Eight high-profile incidents analyzed from media coverage.
- 50% of cases showed evidence of hindsight bias.
- Recommendations involved blaming individuals.
- Included disciplinary actions



# Incorrect Radiation Dose Incident (2014)

Prostate cancer patient (“Mr. A”) received a much higher dose than prescribed.
Cause: *Wedge monitor units were missing in two of four beams.*
The error went undetected for months, until severe skin toxicity appeared.



Source: https://www.hdc.org.nz/decisions/search-decisions/2017/16hdc00650/

# Incorrect Radiation Dose Incident (2014): RCA Findings

## **Contributing** conditions:

- Excessive workload and time pressure on staff.
- Stressful work environment and limited safety margins.

## **Recommendation**:

- Measure diodes for all treatment fields to prevent recurrence.

Source: https://www.hdc.org.nz/decisions/search-decisions/2017/16hdc00650/

# Incorrect Radiation Dose Incident (2014): Limitations of RCA

**Hindsight bias:** Overemphasis on what staff "should have seen."

**Contradictory recommendation:** Measuring diodes for *all* fields does not align with the initial findings.

**New risks created:** Recommendation increases workload and stress, potentially introducing further errors.

**Systemic factors underexplored:** Culture, process design, and automation gaps not fully addressed.

Source: https://www.hdc.org.nz/decisions/search-decisions/2017/16hdc00650/

# Addressing the Healthcare Safety Challenge

- Traditional RCA methods identify limited systemic factors in incidents.
- Incident analyses typically require 8-12 hours using traditional approaches.
- AI introduces novel incident types and failure modes to consider.
- Emergent system behaviors cannot be predicted from individual components alone.
- Complex human-AI dependencies require new frameworks for analysis.

# Hybrid Root Cause Analysis: Balancing Speed and Depth

IHI emphasizes root cause analysis by frontline workers for accuracy.

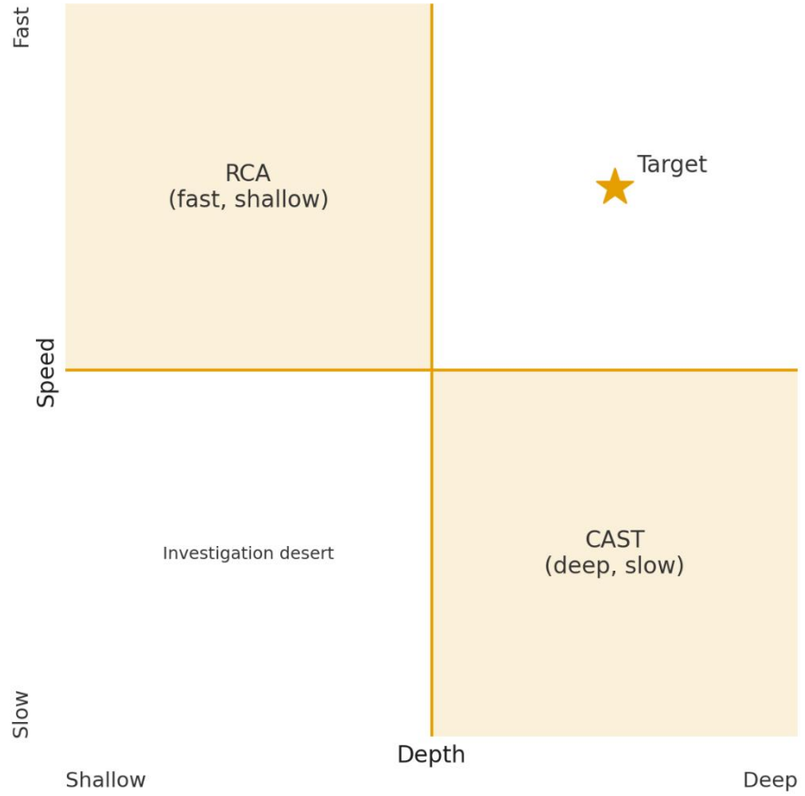
Traditional RCA is fast but may overlook systemic factors.

CAST provides deep systemic insights but is time-intensive.

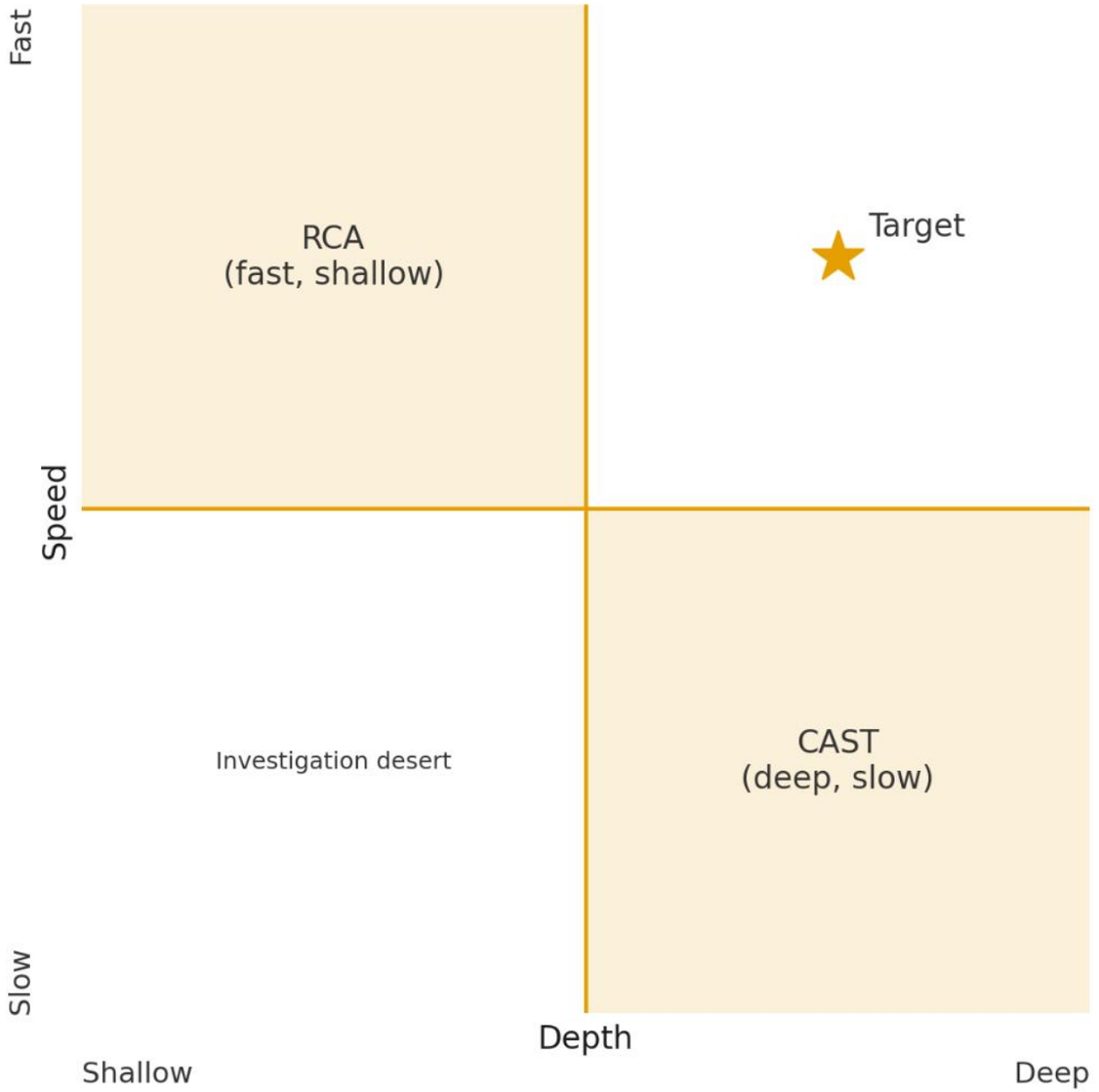
Hybrid approach starts with AI to accelerate CAST analysis.

Final analysis is completed collaboratively by the clinical team.





# Hybrid Root Cause Analysis: Balancing Speed and Depth



# Hybrid Root Cause Analysis: Balancing Speed and Depth

IHI emphasizes root cause analysis by frontline workers for accuracy.

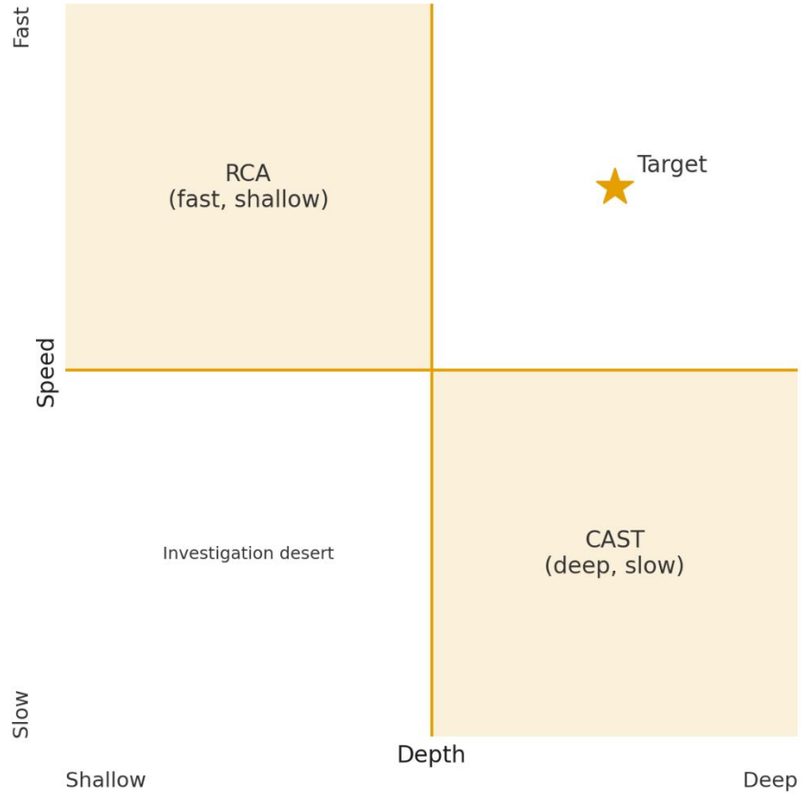
Traditional RCA is fast but may overlook systemic factors.

CAST provides deep systemic insights but is time-intensive.

Hybrid approach starts with AI to accelerate CAST analysis.

Final analysis is completed collaboratively by the clinical team.





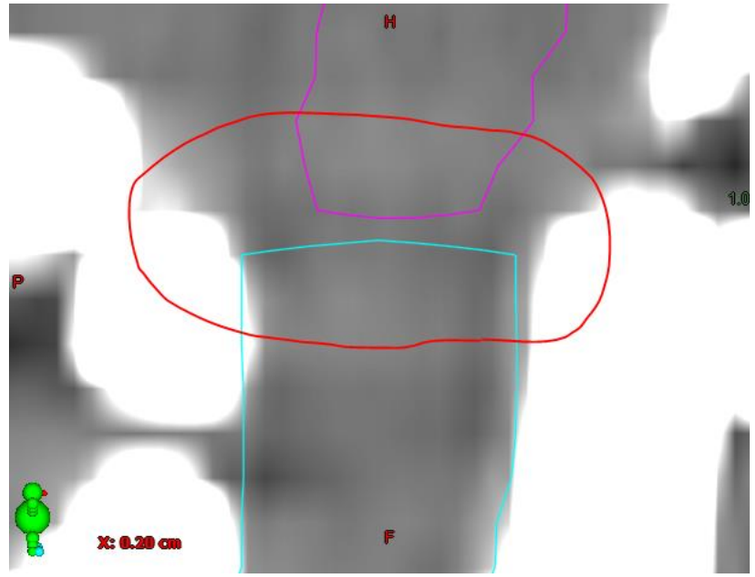
# Case study: Gap between contours by AI

AI software produced inaccurate contour gaps.

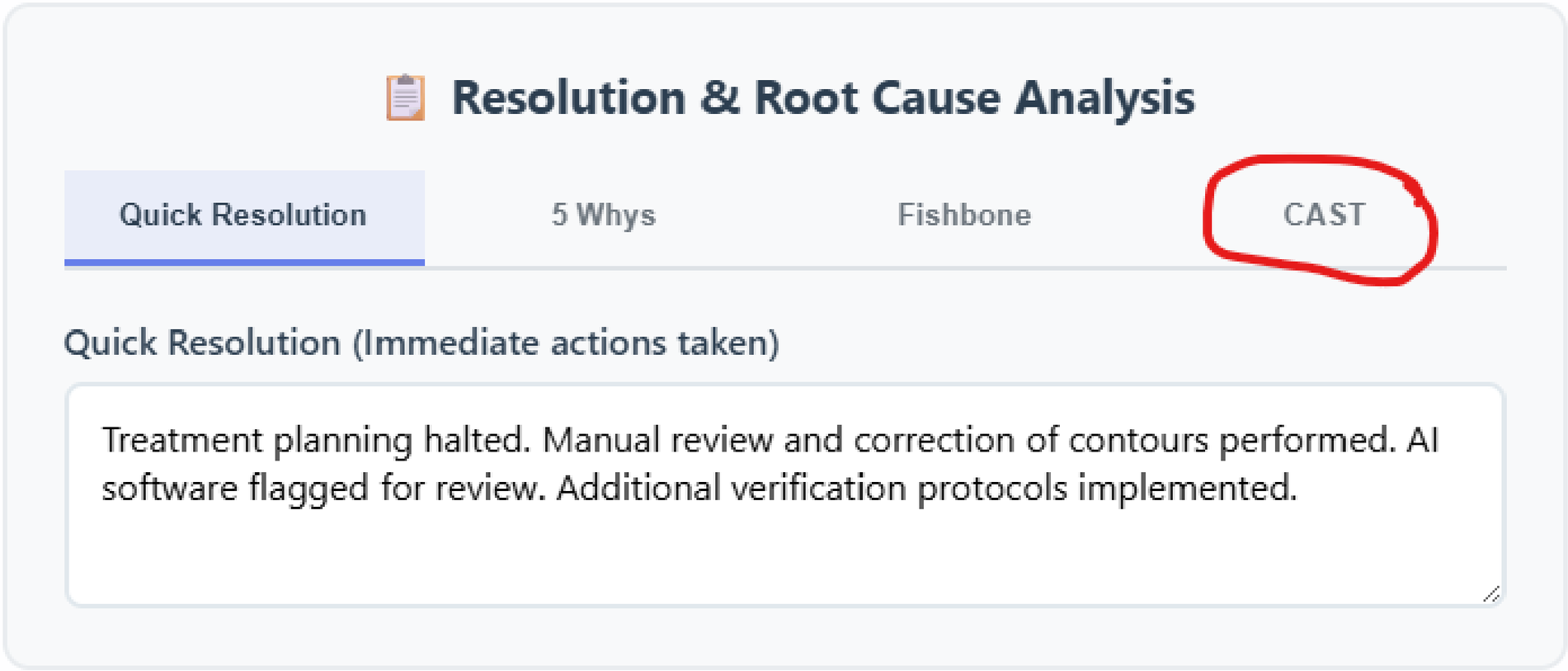
Dosimetrist failed to detect the contour gap.

Doctor missed the error during review process.

Physicist identified the error during final checks.



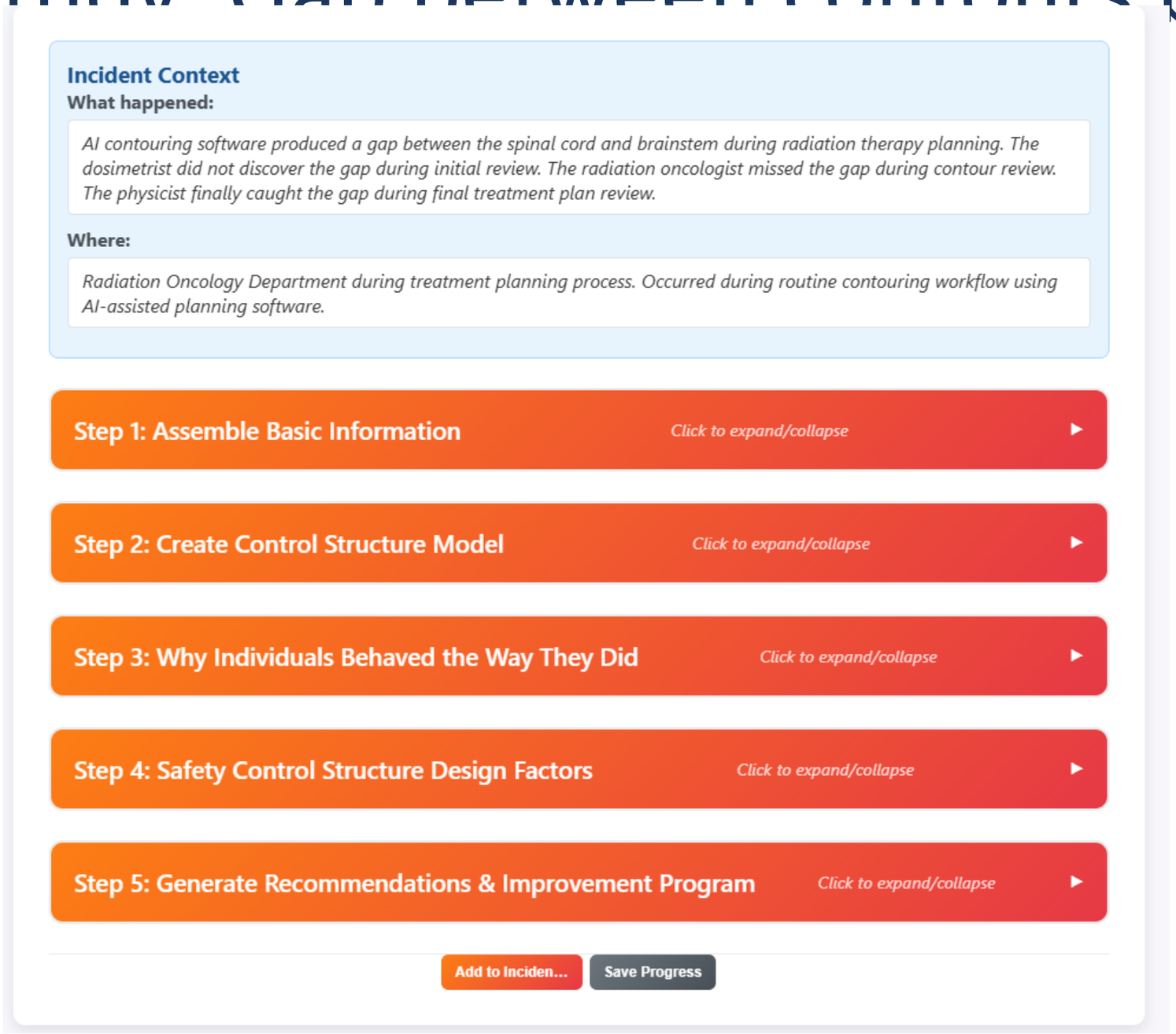
# Case study: Gap between contours by AI



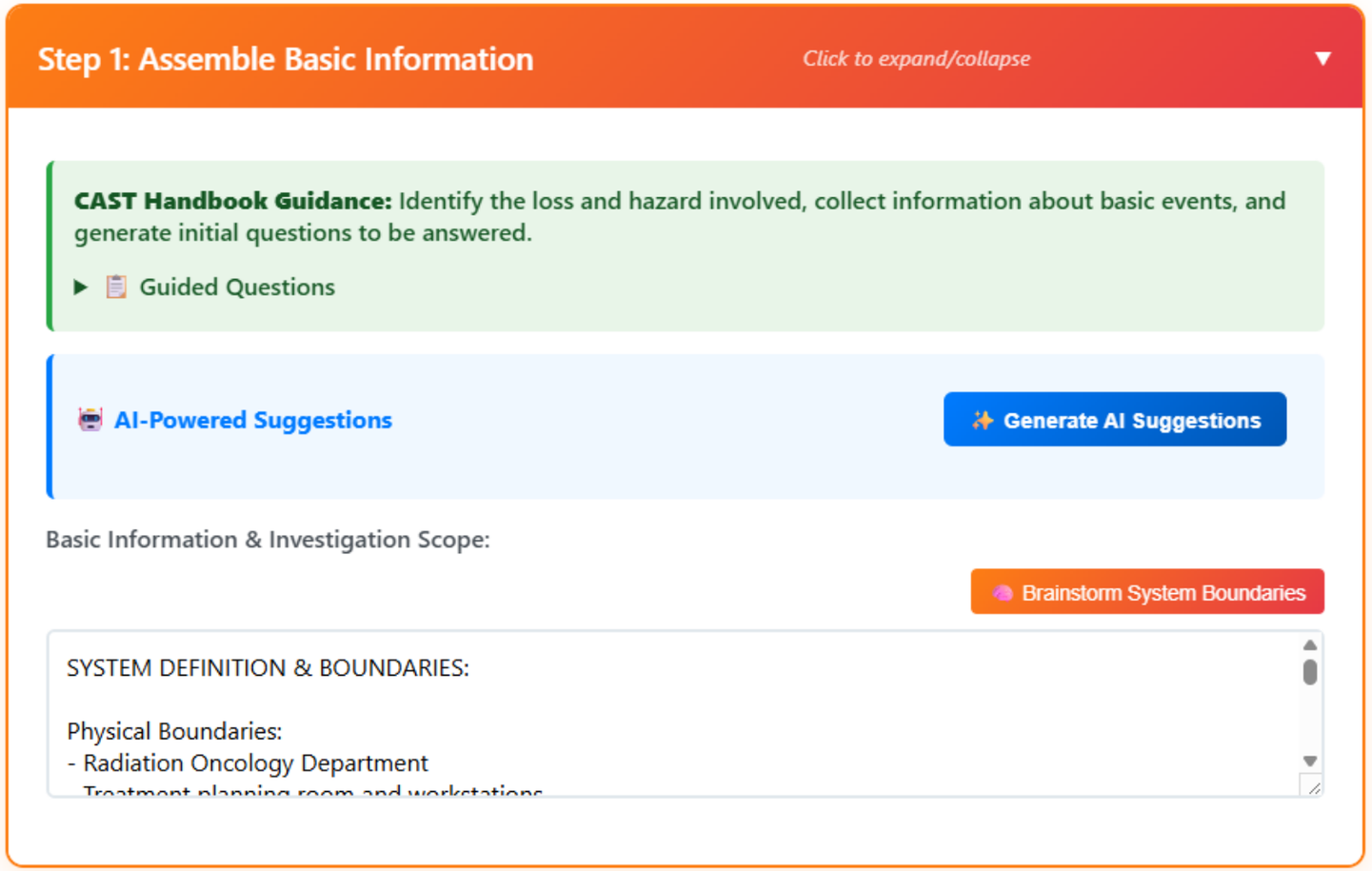
# Our Innovation: AI-Enhanced CAST

| | |
|---|---|
| **AI-Guided Analysis** | • AI provides context-specific CAST step guidance |
| **Automated Pattern Recognition** | • AI identifies systemic patterns humans typically miss and then humans supervise and piggyback |
| **Structured Methodology** | • Platform makes CAST accessible to non-experts |
| **Efficiency Gains** | • Systems thinking becomes practical for busy clinicians |

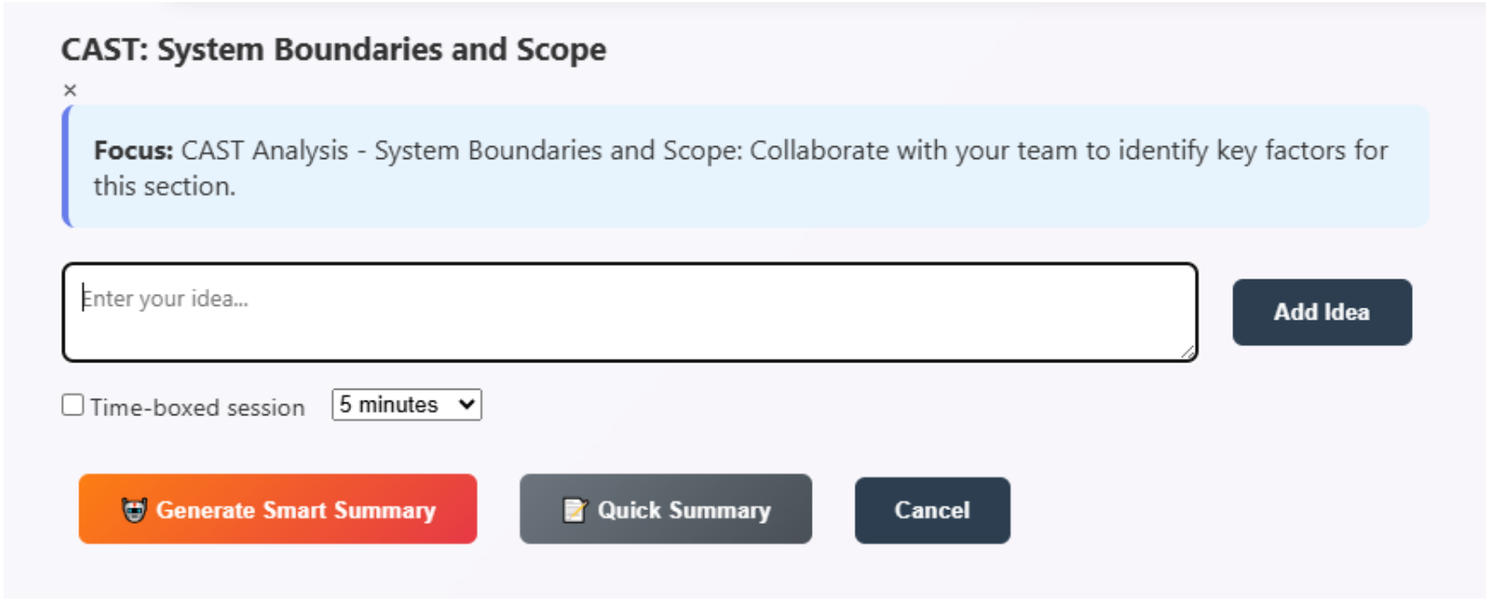
# Case study: Gap between contours by AI



# Case study: Gap between contours by AI



# Case study: Gap between contours by AI: Brainstorming

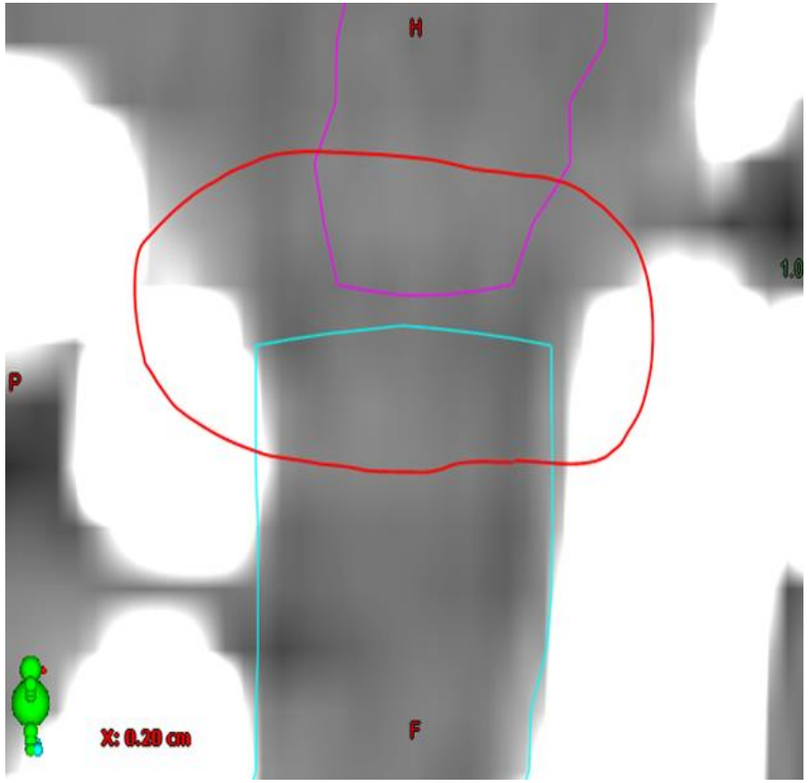


# Key Findings - Loss and Hazard

Potential underestimation of radiation dose to spinal cord and brainstem.

AI contouring software created a gap between critical structures.

This gap risks over-dosing vital organs during treatment.



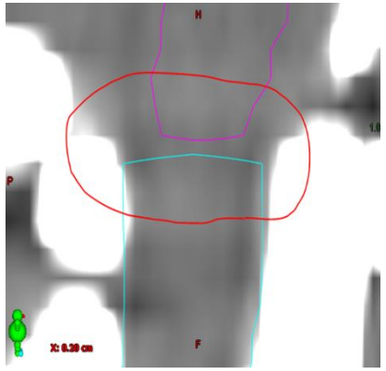
# Initial Questions for Analysis

Why did AI produce the gap?

Why did the dosimetrist not discover it?

Why did the doctor miss it during review?

What processes/checks existed, and why did they fail until physicist review?

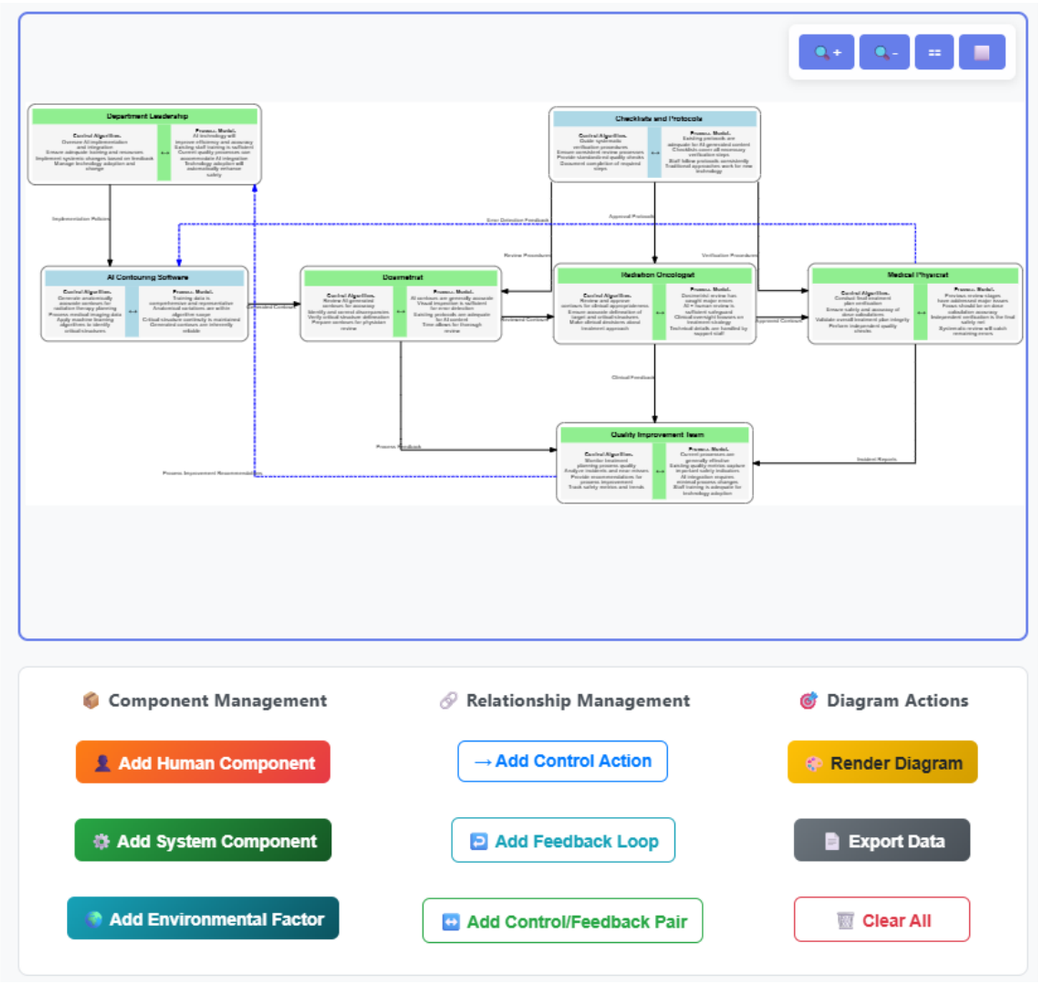


## Step 1 Initial Questions for Analysis

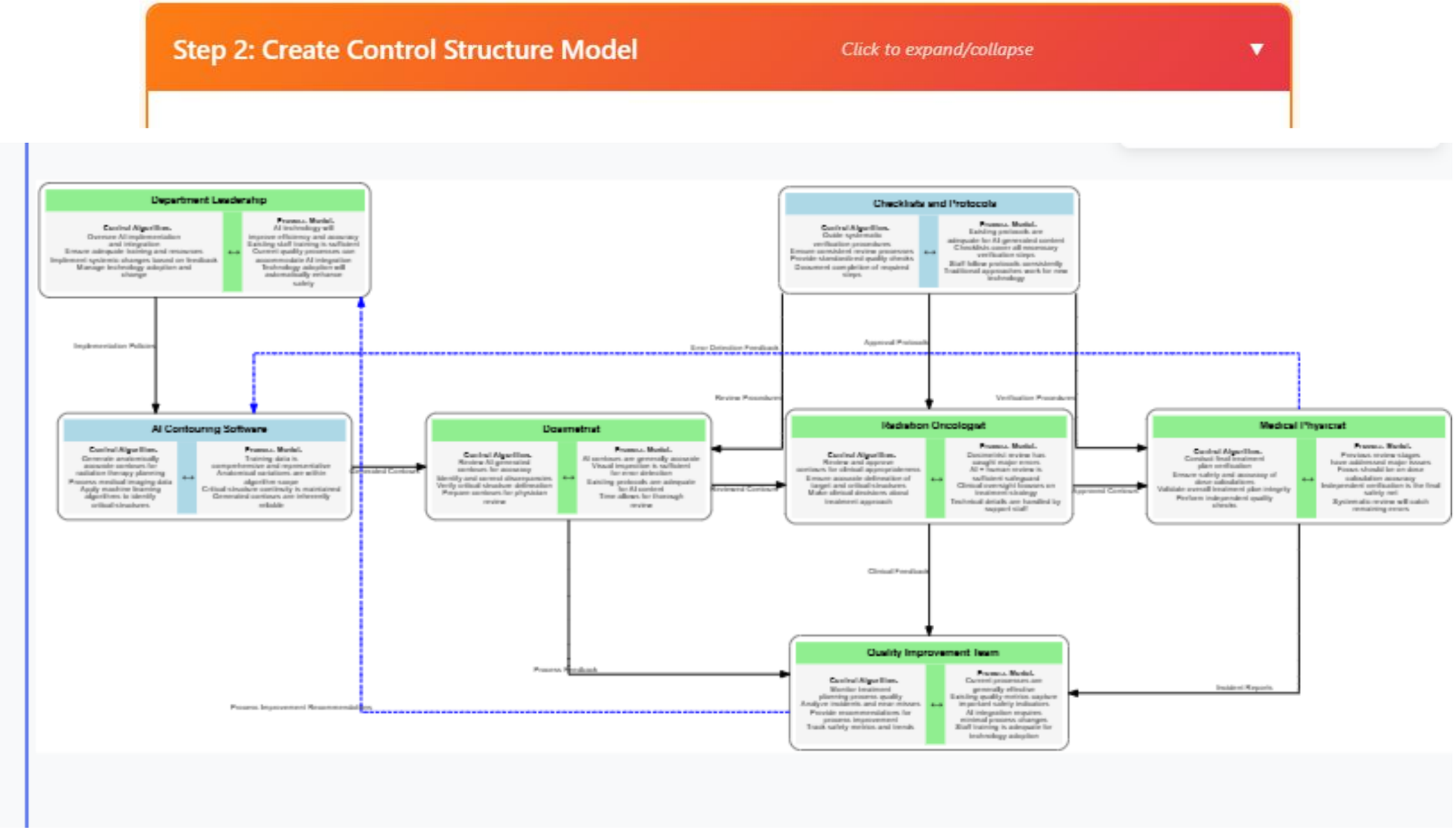
| Actors | Questions |
|---|---|
| **AI Contouring Software** | Why did it produce a gap? Known limitations or bugs? |
| **Dosimetrist** | Why was the gap not discovered? Training or awareness issues? Time/workload pressures? |
| **Doctor (Radiation Oncologist)** | Why was the gap missed in review? Reliance on dosimetrist's review? Distractions or competing demands? |
| **Physicist** | How was the error caught? What checks/processes led to discovery? |
| **Checklists** | Comprehensive and practical? Included contour verification? Readily available and followed? |
| **QI Team** | Similar incidents reviewed? Recommendations implemented? |
| **Contour Round** | Conducted effectively? Adequate expertise and time? |
| **Incident Learning System (ILS)** | Was the incident reported? Were trends/insights identified? |
| **Leadership** | Adequate training and resources? Systemic changes from feedback? |

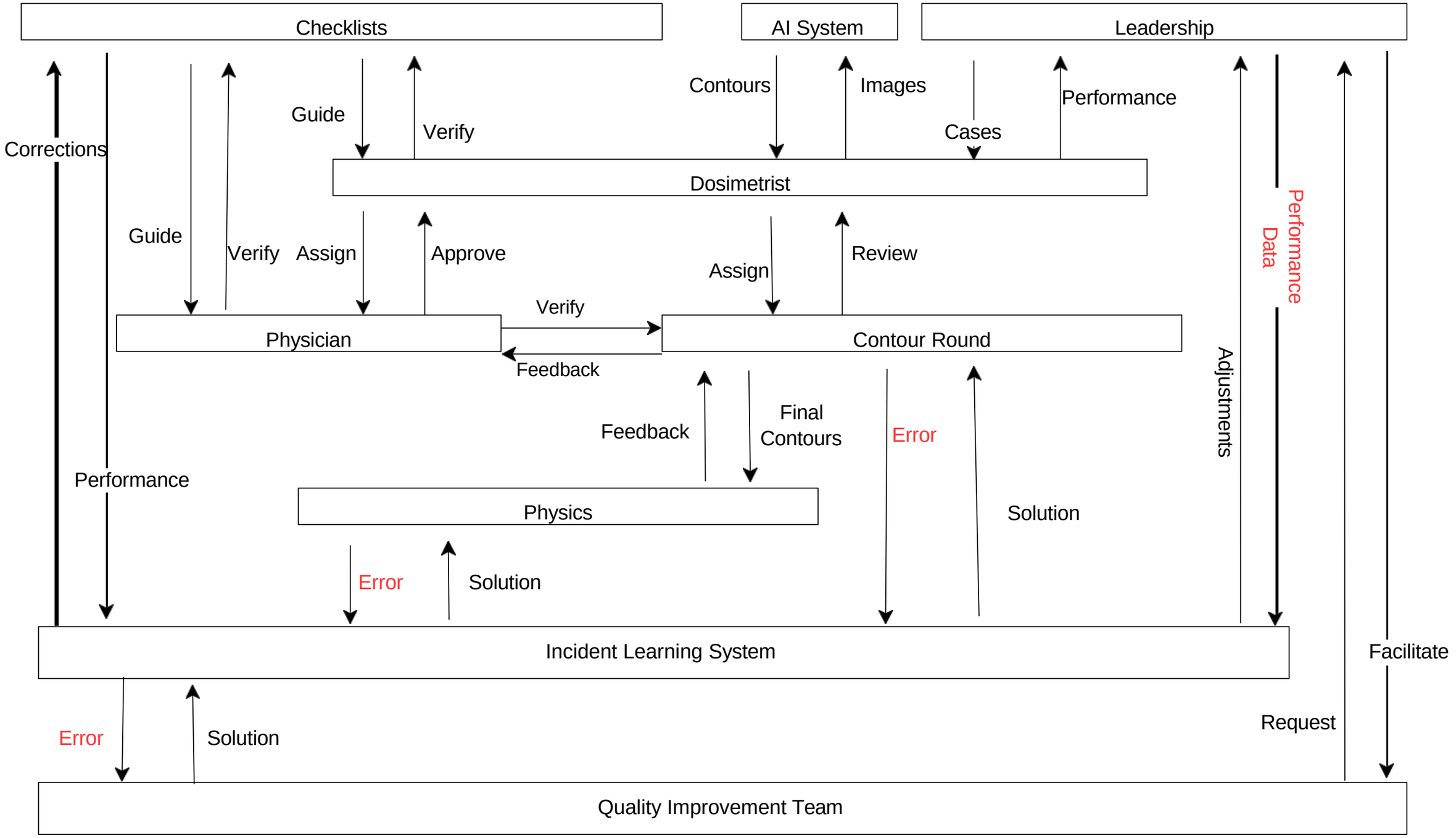
# Case study: Gap between contours by AI



# Case study: Gap between contours by AI




Checklists
AI System
Leadership
Corrections
Guide
Verify
Contours
Images
Cases
Performance
Dosimetrist
Guide
Verify
Assign
Approve
Assign
Review
Verify
Physician
Contour Round
Feedback
Performance Data
Adjustments
Feedback
Final Contours
Error
Performance
Physics
Solution
Error
Solution
Incident Learning System
Facilitate
Request
Error
Solution
Quality Improvement Team

# Identify Potential Systemic Issues

| Area | Questions |
|---|---|
| **Communication** | Are there gaps between dosimetrist, doctor, physicist, and other controllers? |
| **Procedures** | Are there standardized processes for reviewing AI-generated contours? |
| **Training & Competency** | Are staff adequately trained in AI software use? |
| **Electronic Medical Record (EMR)** | Does the EMR require checklist completion before tasks are finalized? |
| **Checklists** | Are they comprehensive and followed correctly? Are they too long or impractical? |
| **Quality Improvement (QI) Team** | Is the team effectively monitoring and improving the process? |
| **Contour Round** | Is it conducted effectively with the necessary expertise and time? |
| **Incident Learning System (ILS)** | Is it capturing and analyzing incidents effectively? |
| **Leadership** | Is adequate support provided? Are systemic changes being implemented? |

# Step 3: Why Did Individuals Behave This Way? (Actors 1–4)

| Actor | Responsibilities / Contribution / Why |
|---|---|
| **AI Contouring Software** | **Resp.:** Auto-generate contours.<br>**Contrib.:** Produced gap between spinal cord & brainstem.<br>**Why:** • Mental Model Flaws: Algorithm limitations/bugs. • Contextual Factors: Lack of testing/validation; insufficient updates. |
| **Dosimetrist** | **Resp.:** Review AI contours.<br>**Contrib.:** Did not discover gap.<br>**Why:** • Mental Model Flaws: Trusted AI accuracy. • Contextual Factors: High workload; limited training on AI; weak checklists. |
| **Physician (Radiation Oncologist)** | **Resp.:** Approve contours.<br>**Contrib.:** Missed gap in review.<br>**Why:** • Mental Model Flaws: Relied on dosimetrist. • Contextual Factors: Distractions; checklist lacked contour verification. |
| **Physicist** | **Resp.:** Final safety check.<br>**Contrib.:** Caught the error.<br>**Why:** • Mental Model Flaws: Initially trusted others, but did a thorough check. • Contextual Factors: Effective checklist use in final review. |

# Step 3: Why Did Individuals Behave This Way? (Actors 5–9)

| Actor | Responsibilities / Contribution / Why |
|---|---|
| **Checklists** | **Resp.:** Standardize verification.<br>**Contrib.:** Missed critical structure checks.<br>**Why:** • Mental Model Flaws: Assumed checklist was comprehensive. • Contextual Factors: Rarely updated, not tailored to new risks. |
| **QI Team** | **Resp.:** Monitor & improve processes.<br>**Contrib.:** Missed prior similar incidents.<br>**Why:** • Mental Model Flaws: Believed processes were sufficient. • Contextual Factors: Weak data analysis; no feedback loop. |
| **Contour Round** | **Resp.:** Multidisciplinary review.<br>**Contrib.:** Did not catch gap.<br>**Why:** • Mental Model Flaws: Trusted AI output. • Contextual Factors: Limited time/expertise; focus not on critical structures. |
| **Incident Learning System (ILS)** | **Resp.:** Capture & analyze incidents.<br>**Contrib.:** Did not flag similar past issues.<br>**Why:** • Mental Model Flaws: Believed all relevant incidents captured. • Contextual Factors: Weak reporting/analysis; poor integration. |
| **Leadership** | **Resp.:** Provide training & systemic support.<br>**Contrib.:** Training/resources insufficient.<br>**Why:** • Mental Model Flaws: Assumed current resources were enough. • Contextual Factors: Financial/time pressure; weak focus on continuous improvement. |

# Additional Questions Raised

| Focus Area | Key Questions |
|---|---|
| **AI Software** | Why did it produce a gap between spinal cord and brainstem? Why was comprehensive testing/validation lacking? |
| **Training** | Why were dosimetrist and doctor not trained on AI limitations? |
| **Checklists** | Why were checklists not regularly updated? |
| **QI Team** | Why did the team not identify or address similar incidents? |
| **Contour Round** | Why was it not conducted with sufficient time and expertise? |
| **Incident Learning System (ILS)** | Why was it not capturing and analyzing incidents effectively? |
| **Leadership** | Why did leadership not provide adequate training and resources? |

# Step 4: Causal Factors in Safety Control Design

| Systemic Issue | Causal Factors |
|---|---|
| **Ill-Defined Responsibility & Accountability** | • No clear guidelines on roles/responsibilities of dosimetrist, doctor, physicist. • Redundant responsibilities → assumptions others would catch errors. |
| **Communication & Coordination Problems** | • Poor handoff and lack of formal communication channels. • Weak multidisciplinary review (contour round). |
| **Safety Culture** | • Over-reliance on AI without verification. • Lack of “Just Culture” to encourage reporting/learning. • Complacency from prior AI success. |
| **Inadequate Management of Change (MoC)** | • No formal MoC process to evaluate AI risks. • Insufficient staff training and resources for new technology. |
| **Incomplete Safety Information System (SIS)** | • ILS failed to capture/analyze incidents comprehensively. • Poor data integration and trend analysis. • Weak feedback mechanisms for improvement. |
| **Economic & Resource Constraints** | • Budget constraints → high workload, low staffing. • Pressure for efficiency over safety. |
| **Organizational Design & SMS** | • Decision-making without coordination. • Lack of a robust safety management system. |
| **Additional Systemic Factors** | • Gaps in AI training programs. • Outdated procedures and checklists. • Insufficient oversight of safety recommendations. |

# Step 5: Systemic Recommendations

| Focus Area | Key Recommendations |
|---|---|
| **Clarify Roles & Responsibilities** | Define unambiguous responsibilities for dosimetrist, doctor, physicist. Ensure accountability while minimizing redundant checks. |
| **Improve Communication & Coordination** | Establish formal handoff procedures. Strengthen multidisciplinary contour rounds. Use Static Sequential with Verification (one reads, others verify). |
| **Foster a Safety Culture** | Promote “Just Culture” → learning, not blame. Encourage transparent reporting. Train against over-reliance on AI. |
| **Management of Change (MoC)** | Implement a formal MoC framework for new tech. Provide training and resources for adapting to AI integration. |
| **Safety Information System (SIS)** | Strengthen ILS with better data collection, analysis, feedback. Integrate with other systems for centralized insights. |
| **Economic & Resource Constraints** | Maintain adequate staffing. Balance efficiency with safety. Prevent cost-saving from undermining care. |
| **Organizational Design & SMS** | Foster coordination through huddles & QI meetings. Centralize decision-making but decentralize execution. Build a robust system for oversight & improvement. |
| **Training & Procedures** | Create AI-focused training (limitations, error patterns). Regularly update procedures & checklists. Ensure checklists are concise, role-specific. |

# What Humans Added Beyond AI

**Context recognition:**

Understood protocol variations and anatomy not captured by AI.

**Error sense-making:**

Interpreted why the contour gap escaped detection across roles.

**Trade-off navigation:**

Balanced throughput, quality, and safety under time pressure.

**Actionable remedies:**

Proposed checklist updates, clarified handoffs, and feedback loops.

# Case Study: AI Contouring Incident

## Traditional RCA Result

- Staff should check AI output more carefully
- Need additional training on AI systems
- Implement checklist reminder

## CAST Result

- AI confidence metrics not displayed in workflow
- No feedback loop for AI learning from corrections
- Workflow designed for human-only process
- Training data bias in edge cases
- Interface design promotes automation bias

**Quality Improvement Team**

Monitors and proposes solutions during huddles and QI meetings

**Huddle**

Discuss yesterday's issues, today and tomorrow's cases

**Incident Learning System**

Keeps records of issues and their solutions

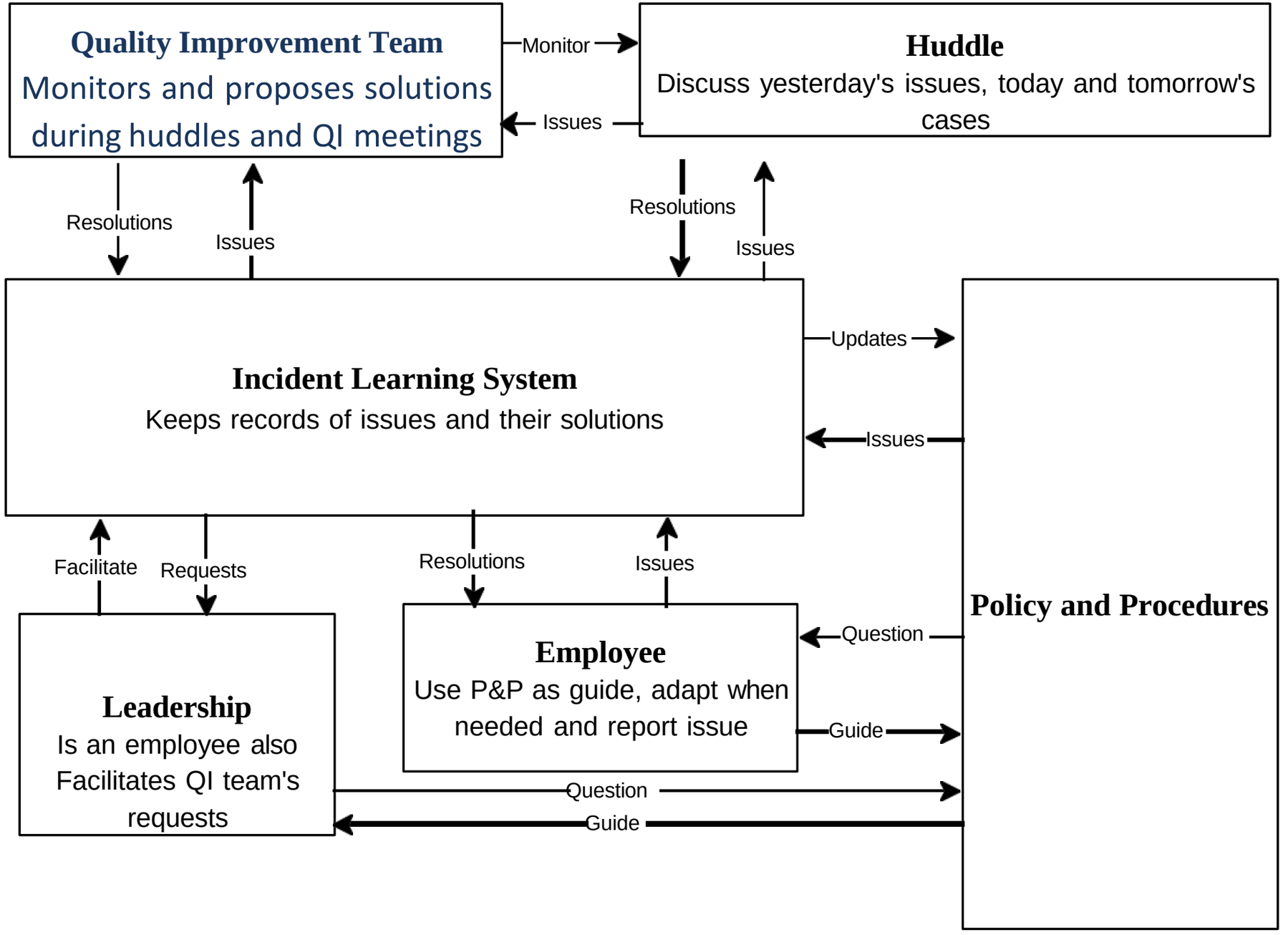
**Policy and Procedures**

**Leadership**

Is an employee also Facilitates QI team's requests

**Employee**

Use P&P as guide, adapt when needed and report issue


Quality Improvement Team
Monitors and proposes solutions during huddles and QI meetings
Monitor
Issues
Huddle
Discuss yesterday's issues, today and tomorrow's cases
Resolutions
Issues
Resolutions
Issues
Incident Learning System
Keeps records of issues and their solutions
Updates
Issues
Policy and Procedures
Facilitate
Requests
Resolutions
Issues
Leadership
Is an employee also Facilitates QI team's requests
Employee
Use P&P as guide, adapt when needed and report issue
Question
Guide
Question
Guide

## Case Study: AI Contouring Outcome

CAST revealed that the incident wasn't about human error, but about system design that didn't account for human-AI collaboration patterns.

## Conclusions: Was AI-Enhanced CAST Effective?

**Clear Answer: Yes, Highly Effective**

**Key "AHA!" Moments from Our Work**

**Context-aware Guidance:**

- The AI's ability to provide specific, step-by-step guidance on CAST allowed for a structured and highly accurate analysis, validating the work of experts and providing a clear path forward.

**Discovery of the Unseen:**

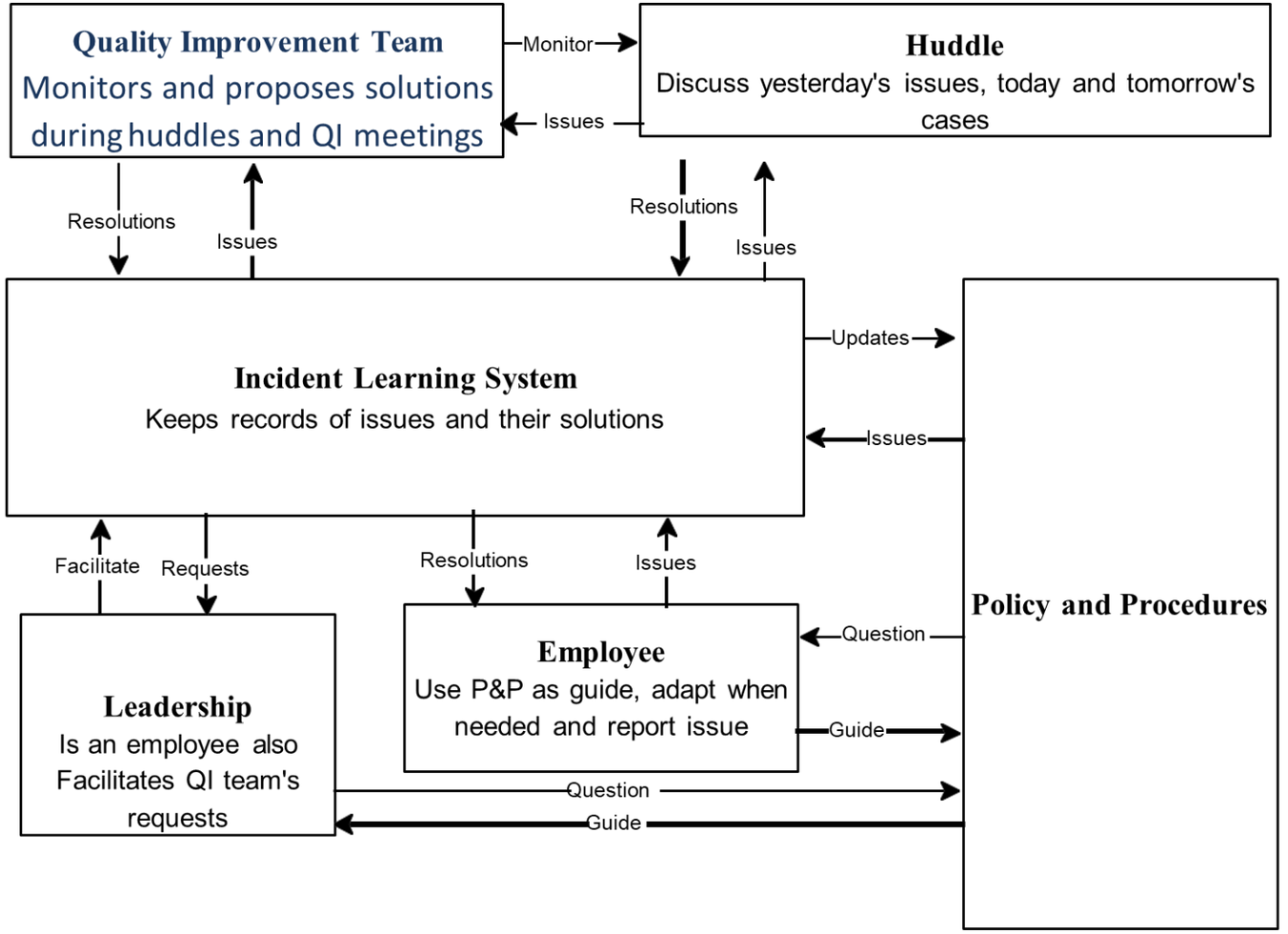
- CAST and AI identified complex, systemic patterns that are typically overlooked by human analysis, leading to a deeper and more comprehensive understanding of the problem.

**Scalable Expertise:**

- We made a complex methodology accessible and consistently applicable to non-experts, democratizing systems thinking and allowing for wider adoption across teams.

# Conclusion

- Shift focus from individual blame to systemic solutions.
- Leadership should support decentralization and continuous improvements.
- Resulting in safer, more adaptive healthcare systems.



# Conclusions: What Would Have Been Missed Without This Work?

Without CAST, we would have missed the crucial, systemic factors.

AI helped to streamline the process.

The methodology would have remained confined to a small group of experts,

Significant time savings and scaling effectively.