Operational Epidemiology: An Outbreak Investigation Approach to F-22 Physiologic Incidents

RYAN MAYES, PhD, MPH
U.S. AIR FORCE SCHOOL OF AEROSPACE MEDICINE

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F-22 Background

- U.S. Air Force-exclusive 5th-generation fighter
- Multiple unexplained physiologic incidents among F-22 pilots 2008-2012
  - Fleet-wide standdown May-Sept 2011
  - Incidents continued to occur after return-to-fly (21 Sept 2011)
- Multi-year investigation into cause of incidents, great deal of public attention
  - Several investigatory bodies involving multiple government agencies as well as industry
- F-22 Task Force concluded that aircrew flight equipment (AFE) was a major cause of F-22 physiological incidents
Traditional Outbreak Investigation Steps*

1. Field work preparation
2. Establish outbreak existence
3. Confirm diagnosis
4. Define and identify cases
5. Describe and orient the data in terms of time, place, and person
6. Develop hypotheses
7. Evaluate hypotheses
8. Refine hypotheses and carry out additional studies
9. Implement control and prevention measures
10. Communicate findings
11. (Maintain surveillance)
   • Not included in CDC steps, but often implemented in practice

*CDC: http://www.cdc.gov/excite/classroom/outbreak/steps.htm
Operational Outbreak Investigation: Step 1

Traditional Outbreak Step: (1) Field Work Preparation

F-22 Investigation Application:
- Background research
  - Design/role of F-22
  - Known information on unexplained incidents
- Identify/assemble team
  - Flight surgeon, physiologist, engineer, statistician, epidemiologist, database programmer, physicist, research psychologist, life support expert, etc.
- Identify involved parties & establish communication lines F-22 stakeholders
  - Investigatory bodies (SAB, Task Force, SIBs)
- Determine role in investigation
  - 711th HPW role expanded over time

Lessons Learned:
- Assemble team more quickly
  - Perhaps pre-formed team “on call”
- More analytic capability
  - Enables multiple other steps (establish existence of outbreak, evaluate hypotheses, etc.)
  - Difficult to spin up on short notice
- Better defined roles & responsibilities

Proposed “Operational Outbreak” Step:
(1) Investigation preparation
- Not limited to field work
Operational Outbreak Investigation: Step 2

TRADITIONAL OUTBREAK STEPS: (3) CONFIRM DIAGNOSIS AND (4) DEFINE AND IDENTIFY CASES

F-22 Investigation Application:

- Not possible to confirm diagnosis
  - Unknown cause, undefined outcome
- Formal “case definition” may not be possible
- Identify presumptive cases
- Group cases if possible (will drive hypothesis development)
- Create (working) inclusion/exclusion criteria based on common features, adjust criteria as needed throughout process
  - Example: physiologic symptoms, reduced ability to fly, no known cause BUT exclude if clear mechanical cause
  - Number of cases changed as inclusion/exclusion criteria and understanding of incidents matured

Lessons Learned:

- This step must be flexible, will be iterative
- Vital to establish a place to start
- Ensure all investigatory bodies aware of inclusion/exclusion criteria

Proposed “Operational Outbreak” Step:

(2) Identify cases, create (dynamic) inclusion & exclusion criteria
Operational Outbreak Investigation: Step 3

**Traditional Outbreak Step: (2) Establish Outbreak Existence**

**F-22 Investigation Application:**

- Compare F-22 hypoxia-like incident rate to other tactical aircraft
  - Per SAB, F-22 rate was higher than “endemic” (F-15E, F-16, etc.)
  - Studies conducted by 711 HPW confirmed higher unknown-cause incident rate
- Denominator data critical
- Comparison establishes need for further investigation

**Lessons Learned:**

- Must identify cases first (have inclusion/exclusion criteria, etc.)
  - F-22 “case definition” a moving target initially, created challenges when communicating to leadership

**Proposed “Operational Outbreak” Step:**

(3) Establish the existence of an outbreak
Operational Outbreak Investigation: Step 4

TRADITIONAL OUTBREAK STEP: (5) DESCRIBE/ORIENT THE DATA

F-22 Investigation Application:

- Traditional outbreak approach not highly relevant for unknown outcomes, hypothesis generation should proceed description of data
- Data collection critical, however
- Gather existing data in central and accessible location
  - 711 HPW became F-22 data repository
  - Established connections with other F-22 data centers
- Identify gaps in knowledge
  - Breathing air quality
  - Breathing air quantity
  - Pilot physiologic outcomes

Lessons Learned:

- Centralized data collection, processing, and analysis vital to investigation
  - Simplifies identification of gaps

Proposed “Operational Outbreak” Step:

(4) Gather existing data, identify gaps
Operational Outbreak Investigation: Step 5

**TRADITIONAL OUTBREAK STEP: (6) DEVELOP HYPOTHESES**

**F-22 Investigation Application:**
- Develop and prioritize hypotheses
  - Prioritization important given size of investigation
  - More resources initially dedicated to “most likely” theories
  - Prioritization enables reevaluation of hypotheses (step 7)
- Establish investigatory structure; how will each hypothesis be approached and who will investigate each?
  - Necessary for very large investigation; hundreds of hypotheses examined
- Consult experts from all pertinent fields
  - Multiple hypothesis types (engineering factors, human factors, man-machine interface)
  - Experts from each field needed
  - Cooperation between Department of Defense and industry critical

**Lessons Learned:**
- Community engagement at this stage would be invaluable
  - Didn’t consult operators until later in process

**Proposed “Operational Outbreak” Step:**
(5) Develop and prioritize hypotheses
Operational Outbreak Investigation: Step 6

**TRADITIONAL OUTBREAK STEP: (7) EVALUATE HYPOTHESES**

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**F-22 Investigation Application:**

- Evaluation (analytic epidemiology)
  - Small numbers problem
    - Solved through simulation, imputation
  - Paired comparisons to evaluate data without known standards
    - Incident pilot vs. wingman
  - Integrity data major challenge
    - Cohort-type approach
    - Topographical analysis
  - Operational data
    - Pulse oximetry, C2A1 analysis, etc.
  - Formal experiments (centrifuge, etc.)
- Tracking
  - Root Cause Corrective Analysis (RCCA) used
  - Useful for grouping hypotheses, consolidating efforts, etc.

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**Lessons Learned:**

- RCCA useful but has limitations
  - Not ideal for physiology or multiple factors

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**Proposed “Operational Outbreak” Step:**

(6) Track and evaluate hypotheses

- Evaluate with empirical data
Operational Outbreak Investigation: Step 7

**TRADITIONAL OUTBREAK STEP: (8) REFINE HYPOTHESES & CARRY OUT STUDIES**

F-22 Investigation Application:

- Apply findings to previous hypotheses, identify remaining gaps
  - No evidence to support that incidents were caused by contaminants
  - No evidence to support that symptoms were due to classic hypoxia
  - Many initial hypotheses ruled out
- Communicate with all stakeholders (include operators/end-users)
  - Pilot input led to additional hypotheses (work of breathing)
- Conduct further studies
  - Altitude chamber
  - Centrifuge
  - Flight testing

Lessons Learned:

- Community input received at this stage proved invaluable
  - Should have engaged with pilots much earlier (when initially developing hypotheses)

Proposed “Operational Outbreak” Step:

(7) Refine hypotheses & carry out additional studies
Operational Outbreak Investigation: Step 8

TRADITIONAL OUTBREAK STEP: (9) IMPLEMENT CONTROL AND PREVENTION MEASURES

F-22 Investigation Application:
- Implement changes when evidence supports
  - Remove C2A1 filter
  - Improve AFE fitting procedures
  - Redesign upper pressure garment (UPG) fill/dump valve
- Track changes over time
  - Allows assessment of impact of those changes
  - C2A1 filter initially installed as mitigation, but may have contributed to incidents

Lessons Learned:
- Communicate control and prevention measures taken

Proposed “Operational Outbreak” Step:
(8) Implement control and prevention measures
Operational Outbreak Investigation: Step 9

Traditional Outbreak Step: (10) Communicate Findings

F-22 Investigation Application:

- Communicate findings:
  - Vitally important, not just to leadership but communicate to operators as well
  - Consistent feedback loop
- Provide inputs for research:
  - Multiple knowledge gaps revealed during investigation
  - Used to direct relevant research
  - F-22 investigation informs research at 711 HPW

Lessons Learned:

- Operators not always informed of progress while investigation underway
- Ongoing communications to F-22 pilots would have been advantageous

Proposed “Operational Outbreak” Step:

(9) Communicate findings and provide inputs for further research
Operational Outbreak Investigation: Step 10

**F-22 Investigation Application:**
- Confirm control measures or other actions have effectively contained outbreak
  - No unexplained physiologic incidents since UPG removed
  - No incidents since C2A1 canisters removed

**Lessons Learned:**
- Continued surveillance helps to further evaluate hypotheses
  - Also helps bolster findings when communicating results to stakeholders and/or decision makers

**Proposed “Operational Outbreak” Step:**
(10) Maintain surveillance
Outbreak Investigation Step Comparison

**Traditional Outbreak Investigation**

1. Field work preparation
2. Establish outbreak existence
3. Verify the diagnosis
4. Define and identify cases
5. Describe and orient the data in terms of time, place, and person
6. Develop hypotheses
7. Evaluate hypotheses
8. Refine hypotheses and carry out additional studies
9. Implement control and prevention measures
10. Communicate findings
11. (Maintain surveillance)

**Proposed Operational Epi Approach**

1. Investigation preparation
2. Identify/group cases, create (dynamic) inclusion/exclusion criteria
3. Establish outbreak existence
4. Gather existing data, identify gaps
5. Develop and prioritize hypotheses
6. Track and evaluate hypotheses
7. Refine hypotheses and carry out additional studies
8. Implement control and prevention measures
9. Communicate findings and provide inputs for further research
10. Maintain surveillance
Operational Epidemiology: Outbreak Investigation Steps

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Questions?

The views expressed are those of the author and do not necessarily represent the official position or policy of the Air Force, the Department of Defense, or the U.S. Government.

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Ryan S. Mayes, PhD, MPH
Ryan.Mayes.2@us.af.mil