Automated Outbreak Detection in Hospitals and Communities

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NIH Models of Infectious Disease Agent Study (MIDAS)

Hospital Outbreak Detection

Hospital Outbreak Detection

- Required of every hospital
- Infection Control program
- Critical elements
  - Correct assessment
  - Timely identification
  - Rapid response
  - Tracking of containment
  - Confidence in resolution

Current Issues in Outbreak Detection

- Incomplete ascertainment
  - Limited surveillance
  - Clinician report
- Routine tracking of a few organisms
  - MRSA, VRE, ESBL
  - Labor intensive
  - Criteria not standardized
  - No statistical basis

Need for Automation

- Outbreaks can involve
  - Any of hundreds of organisms
  - Any hospital unit
  - Any clinical service
  - Medical equipment
- Microbiologic data readily available
- Statistical assessment needed

Ideal Outbreak Detection

- Assesses
  - All pathogens
  - Units, service, antibiotic profile
- Statistically based
- Avoids empiric rules
  - 3 nosocomial cases in 2 weeks

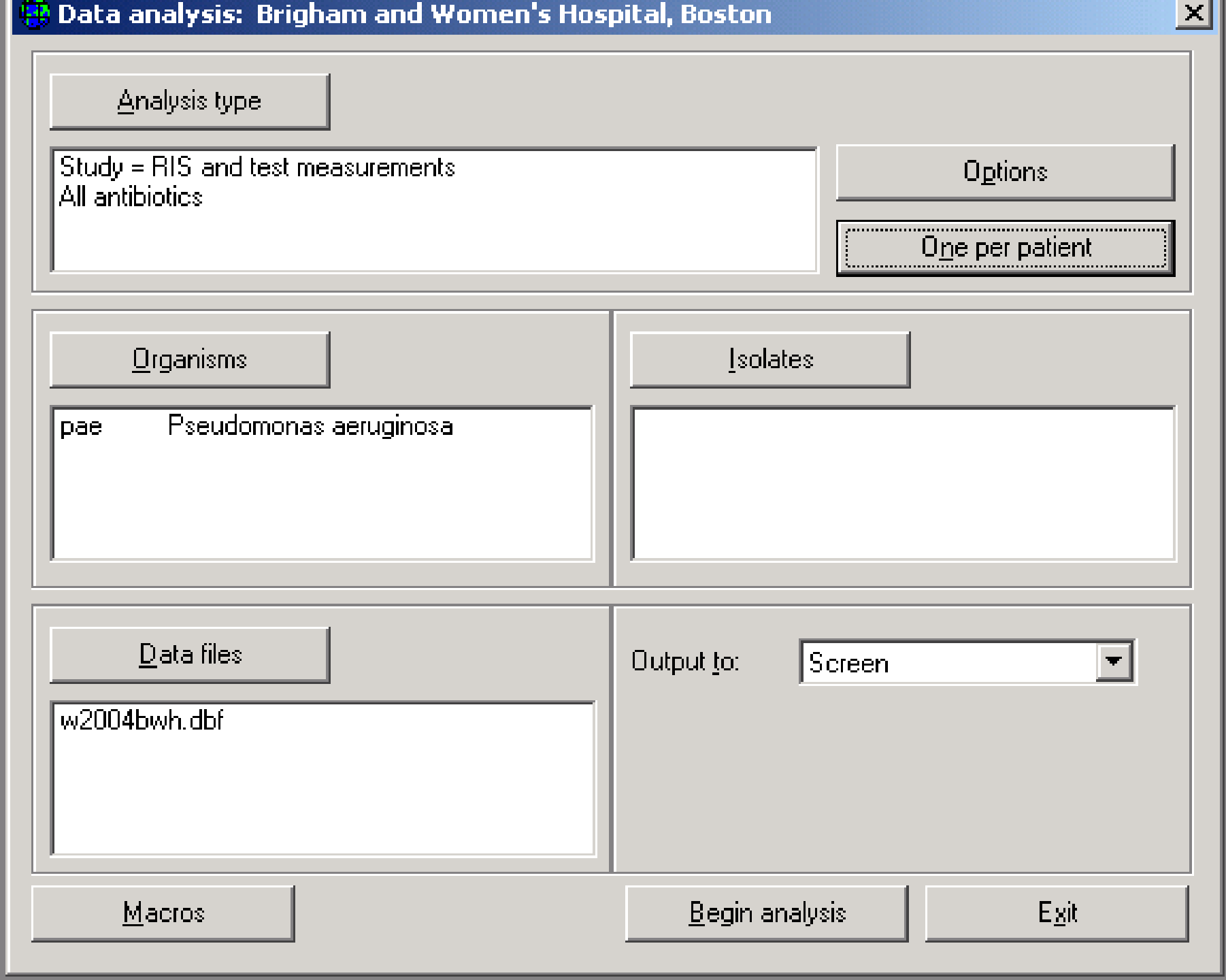
WHONET

- WHO sponsored free software*
- Describes microbiologic data
  - Management
  - Analysis
- 1200 laboratories
- 80 countries
- 17 languages

* www.who.int/drugresistance/whonetsoftware

WHONET Use in the World

- **African Regional Office of WHO (AFRO)**
  - Algeria, Kenya, Namibia, South Africa, Tanzania, Zambia
- **Eastern Mediterranean Regional Office of WHO (EMRO)**
  - Jordan, Kuwait, Lebanon, Libya, Morocco, Oman, Pakistan, Saudi Arabia, Tunisia
- **European Regional Office of WHO (EURO)**
  - Austria, Belgium, Bulgaria, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Georgia, Germany, Greece, Iceland, Ireland, Israel, Italy, Latvia, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Russia, Slovakia, Slovenia, Spain, Sweden, Ukraine, United Kingdom
- **Pan-American Health Organization (PAHO)**
  - Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, Guatemala, Mexico, Nicaragua, Panama, Paraguay, Peru, United States, Uruguay, Venezuela
- **South-East Asian Regional Office of WHO (SEARO)**
  - India, Indonesia, Sri Lanka, Thailand
- **Western Pacific Regional Office of WHO (WPRO)**
  - China, Hong Kong (China), Japan, Republic of Korea, Malaysia, Philippines, Singapore, Taiwan, Viet Nam


Data analysis: Brigham and Women's Hospital, Boston
Analysis type
Study = RIS and test measurements
All antibiotics
Options
One per patient
Organisms
pae Pseudomonas aeruginosa
Isolates
Data files
w2004bwh.dbf
Output to:
Screen
Macros
Begin analysis
Exit

Analysis Results

File Edit Data

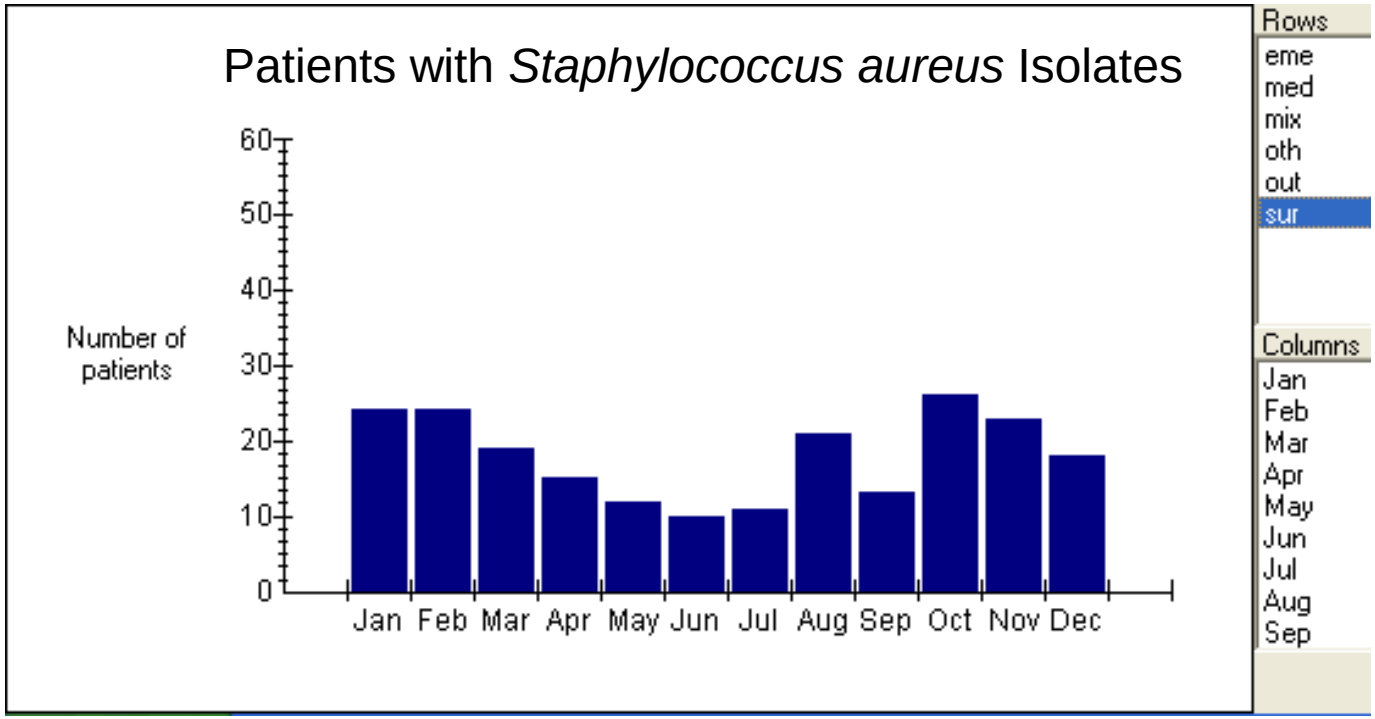
Copy table | Copy graph | Print table | Print graph | Continue

Organism = Staphylococcus aureus ss. aureus (n=336 Isolates)

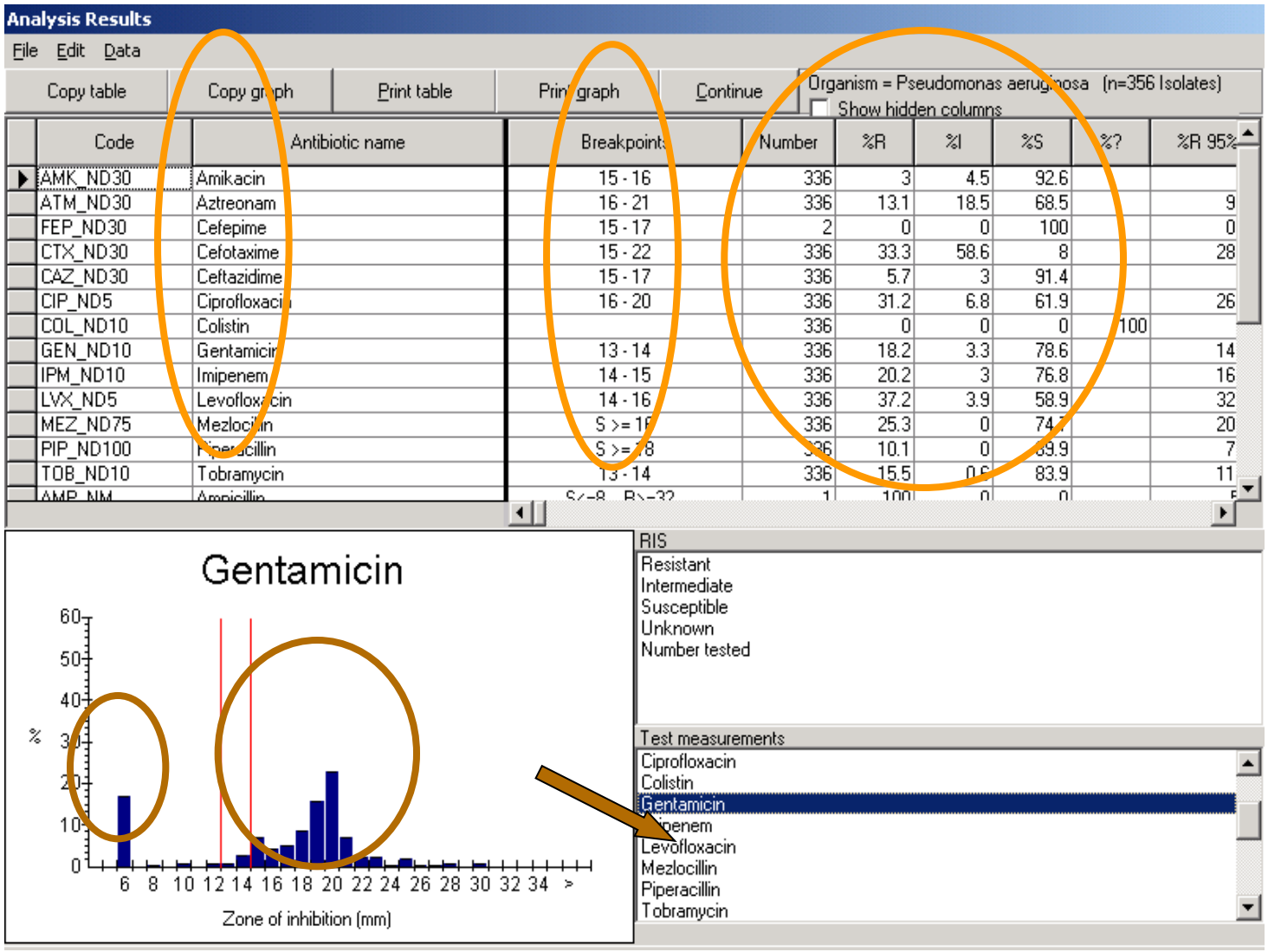
Show hidden columns

OXA_FD1: R

	Code	Department	Number of isolates	(%)	Number of patients	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
▶	eme	eme	4	(1)	4		2							
	med	med	89	(26)	89	4	8	9	6	4	3	11	11	15
	mix	mix	15	(4)	15	1	3	2					1	2
	oth	oth	2	(1)	2			1						1
	out	out	10	(3)	10	1	1	1	2					3
	sur	sur	216	(64)	216	24	24	19	15	12	10	11	21	13

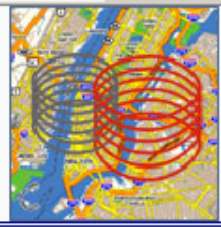


%RIS & Histograms: *Ps. aeruginosa*



SaTScan™

Software for the spatial, temporal, and space-time scan statistics



- Home
- Download [SaTScan v6.0 *October 24 2005*]
- Technical Documentation
- Bibliography
- Data Sets
- Contact Us

Purpose

The SaTScan™ software analyzes spatial, temporal and space-time data using the spatial, temporal, or space-time scan statistics. It is designed for any of the following interrelated purposes:

- To perform geographical surveillance of disease, detect spatial or space-time disease clusters, and see if they are statistically significant.
- To test whether a disease is randomly distributed over space, over time or over space and time.
- To evaluate the statistical significance of disease cluster alarms.
- To perform repeated time-periodic disease surveillance for the early detection of disease outbreaks.

The software may also be used for similar problems in other fields such as archaeology, astronomy, criminology, ecology, economics, engineering, genetics, geography, geology, history or zoology.

Data Types and Methods

SaTScan uses either a Poisson-based model, where the number of events in an area is Poisson-distributed, according to a known underlying population at risk; a Bernoulli model, with 0/1 event data such as cases and controls; a space-time permutation model, using only case data; an ordinal model, for categorical data; or an exponential model for survival time data with or without censored variables. The data may be either aggregated at the census tract, zip code, county or other geographical level, or there may be unique coordinates for each observation. SaTScan adjusts for the underlying inhomogeneity of a background population. It can also adjust for any number of categorical covariates provided by the user, as well as for temporal trends, known space-time clusters and missing data. It is possible to scan multiple data sets simultaneously to look for clusters that occur in one or more of them.

Financial Support and Developers

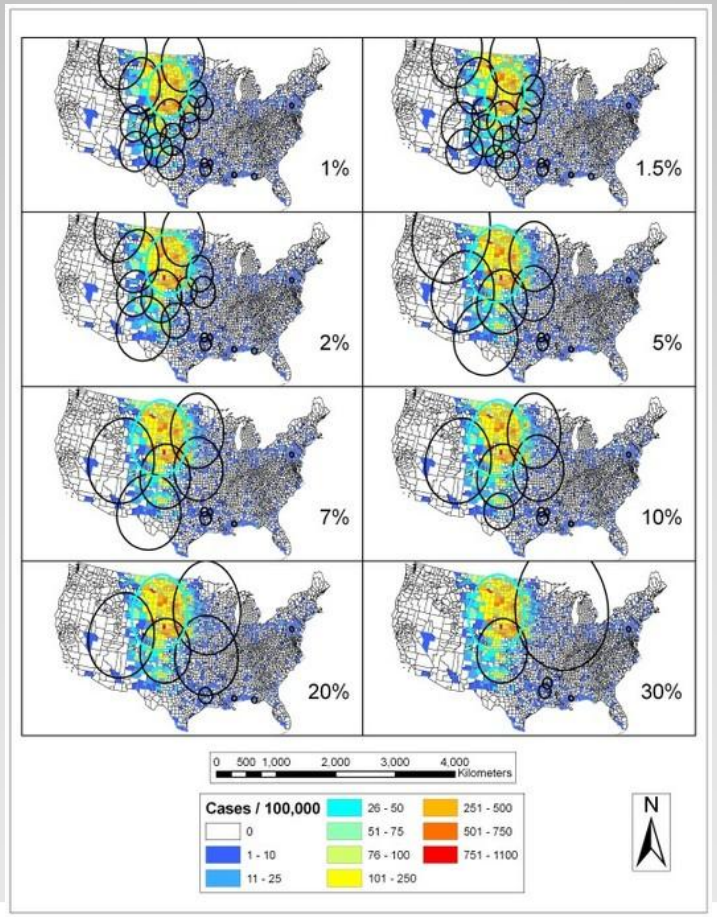
The SaTScan™ software and Web site were developed by Martin Kulldorff together with Information Management Services Inc.

Financial support for SaTScan was received from the following institutions branches and programs:

- **National Cancer Institute**, Division of Cancer Prevention, Biometry Branch [SaTScan v1.0, 2.0, 2.1]
- **National Cancer Institute**, Division of Cancer Control and Population Sciences, Statistical Research and Applications Branch [SaTScan v3.0 (part)]
- **Alfred P. Sloan Foundation**, through a grant to the New York Academy of Medicine (Farzad Mostashari, PI) [SaTScan v3.0 (part), 3.1, 4.0, 5.0, 5.1]
- **Centers for Disease Control and Prevention,** through Association of American Medical Colleges Cooperative Agreement award number MM-0870 [SaTScan v6.0].

Their financial support is greatly appreciated. The contents of SaTScan are the responsibility of the developer and do not necessarily reflect the official views of the funders.

SaTScan – Space and Time Scanning



WHONET-SaTScan

- Links microbiologic data analysis to statistical mining
- Enables hospital outbreak detection
  - Hospital-wide
  - By unit and related unit groups
  - By service and related service groups
  - By antibiotic resistance pattern

WHONET-SaTScan

- **Project Goal:**
  To automate hospital-associated outbreak detection and validate results in a survey of 2 physician leaders of Infection Control

WHONET-SaTScan

- **Study Design:**

  6-year retrospective cohort study

  1) Identify detection algorithm

  2) Evaluate its utility

WHONET-SaTScan

- **Study Population:**
  All patients admitted to
  Brigham & Women's Hospital
  750-bed tertiary academic hospital
  from 2001-2006

Outbreak Detection Methods

- All clinical cultures, 2001-6
- 2001 data for parameterization
- 2002-6 data for outbreak detection

Outbreak Detection
WHONET Data Input

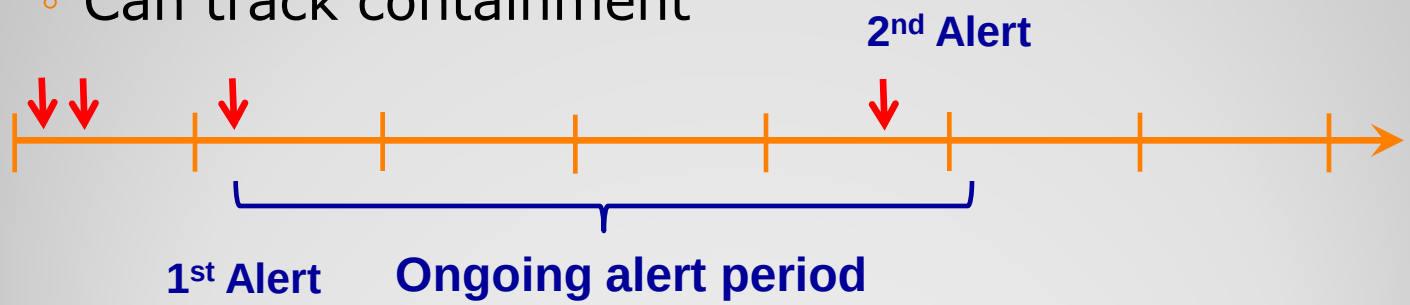
- BWH Culture Results
  - All organisms, 2002-6
  - First-ever per patient
  - >Hospital Day 2
- Data Elements
  - Patient identifiers
  - Organism
  - Date of culture
  - Location of culture
  - Clinical service
  - Antibiotic profile

SaTScan Analysis

- Assesses temporal trends
  - Compares rates across organisms
- Assesses organism-specific rates
  - Using prior baseline in past year (365 days)
  - Stratified by unit, service, antibiotic profile
  - Provides daily alerts

Algorithm Development

- 1st alert must be initiated within 60d
- Alert will exist as long as threshold met
- Daily report of alerts
  - Repeat alert for incremental cases only
  - Can track containment



Example: 3 cases within 5 months triggers alert

Outbreak Alert SaTScan Parameters

- Meaningful statistical threshold
  - One false alert per year per comparison
  - = recurrence interval of 1 in 365
  - = $p<0.0027$
- Max outbreak duration
  - no limit

WHONET SaTScan Report

- Signal Alerts
  - Daily report of all new alerts
  - Repeat alert of same cluster if cases increase
- Alert Data
  - Type of alert
  - 1st alert date
  - 1st culture date
  - Observed cases in outbreak
  - Expected cases in outbreak
  - Recurrence Interval

"Spatial" Assessments

- Entire hospital population
- Patient subsets
  - Hospital units
  - Clinical service
  - Antibiotic resistance profile

Output: Alert Report

- Signal Alerts
  - Daily report of new alerts
  - Repeat alert of same cluster if cases increase
- Alert Data
  - Type of alert
  - 1st alert date and 1st culture date
  - Observed cases in outbreak
  - Expected cases in outbreak
  - Recurrence interval

Algorithm Performance

Is it practical?

2002-6 Outbreak Alerts

- **Median 12 annual alerts (7-16)**
- **Organisms**
  - GP: 36%; GN 53%; Fungi 12%
- **Outbreak Type**
  - Antibiotic Profile 26 (41%)
  - Unit 18 (29%)
  - Hospital-wide 11 (18%)
  - Service 8 (13%)
- **Outbreak Size**
  - 2 patients 12 (20%)
  - 3-5 patients 27 (46%)
  - 6-10 patients 11 (19%)
  - >10 patients 9 (15%)

Does it capture known outbreaks?

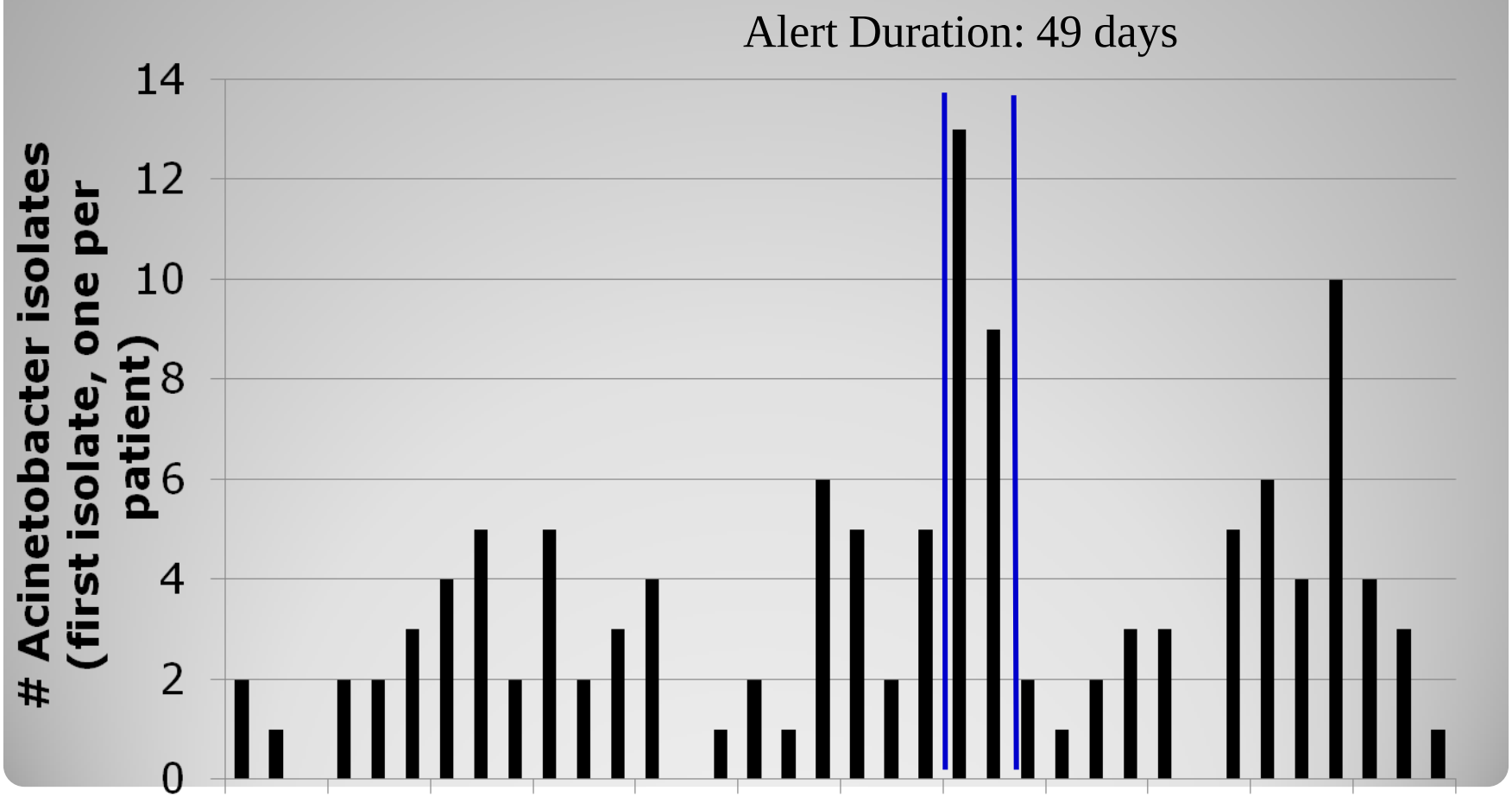
Comparison to Known Outbreaks

- Identified by Infection Control
  - Identified all 4 outbreaks identified by Infection Control program
  - 3 of these were confirmed by PFGE

2004 Alert Summary

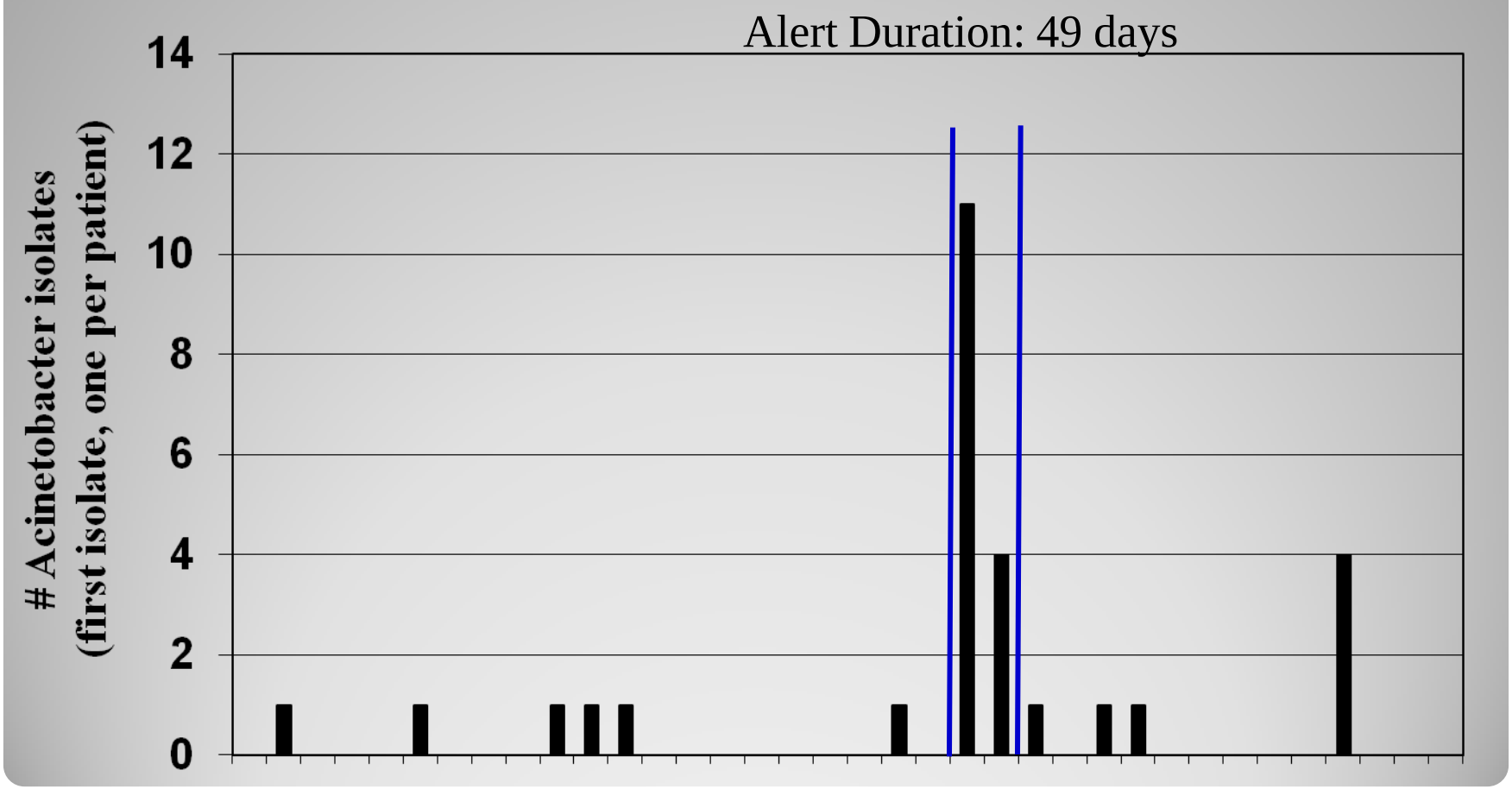
Organism	Signal Type	Observed Cases	Expected Cases	Days to First Signal	Span of Signals	Recurrence Interval	IC Identified
Gram Positive Bacteria							
E faecalis	Resistance profile	4	0.6	18	25	667	N
E faecium (VRE)	Resistance profile	2	0.14	29	17	500	N
S aureus	Ward	7	1.1	6	16	667	N
S aureus (MRSA)	Ward	8	1.4	6	54	10000	Y
Gram Negative Bacteria							
A baumannii [b]	Resistance profile	15	7.5	18	52	10000	Y
A baumannii [b]	Hospital	20	8.3	3	57	625	Y
A baumannii	Ward	4	0.6	3	9	2000	N
B fragilis	Service	2	0.2	4	1	500	N
H influenza	Hospital	13	4.2	18	14	455	N
K oxytoca	Resistance profile	2	0.2	24	12	1111	N
P aeruginosa	Resistance profile	3	0.2	2	7	476	N
S marcescens	Hospital	10	2.8	10	3	2500	N
Fungi							
A fumigatus	Hospital	7	1.4	20	57	417	N

Acinetobacter baumanii Isolates



1st Alert: 8 cases

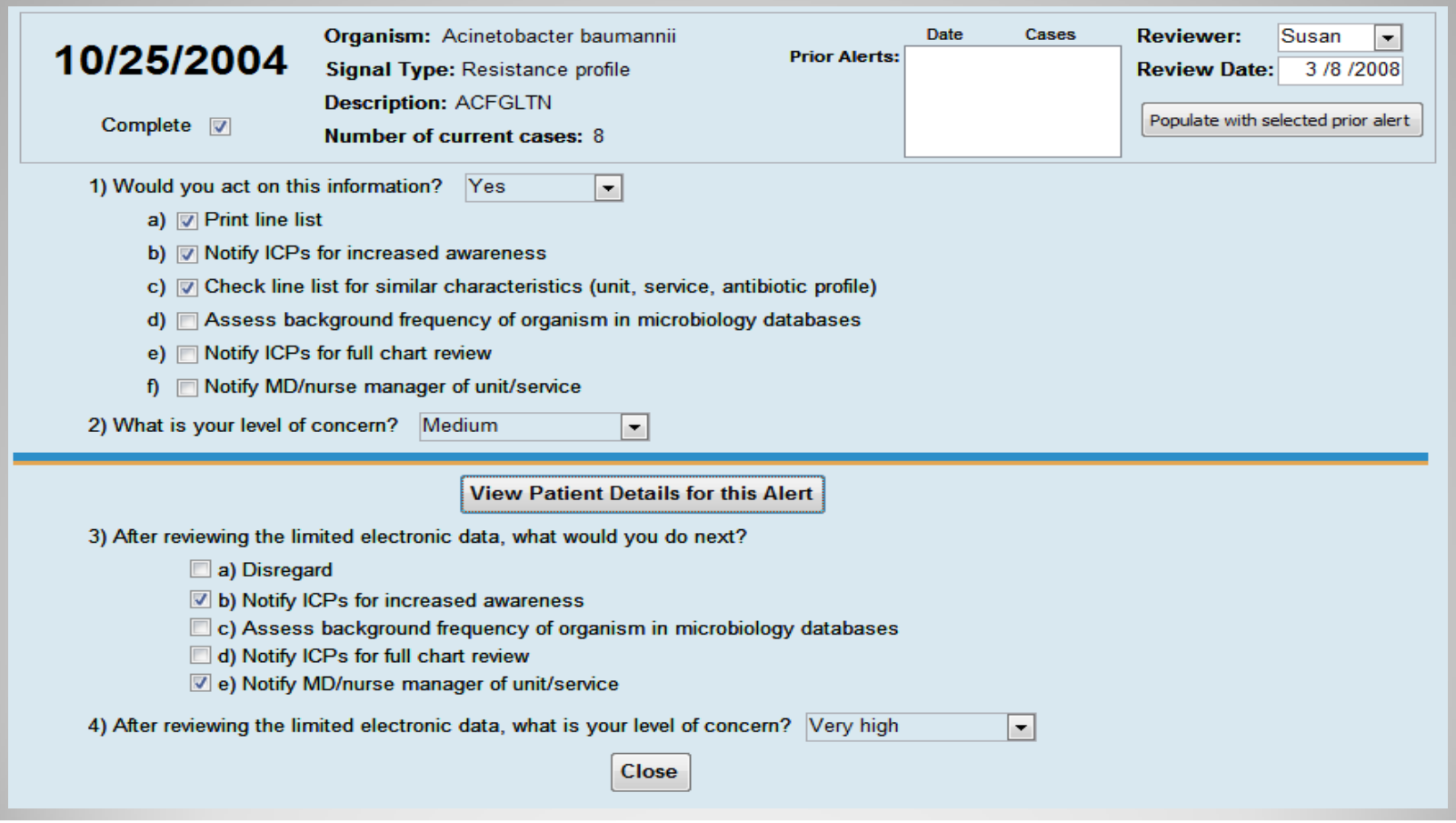
Acinetobacter baumanii by Susceptibility Pattern



1st Alert: 8 cases

Is it useful?

Survey Tool


10/25/2004
Complete
Organism: Acinetobacter baumannii
Signal Type: Resistance profile
Description: ACFGLTN
Number of current cases: 8
Prior Alerts:
Date
Cases
Reviewer: Susan
Review Date: 3 /8 /2008
Populate with selected prior alert
1) Would you act on this information? Yes
a) Print line list
b) Notify ICPs for increased awareness
c) Check line list for similar characteristics (unit, service, antibiotic profile)
d) Assess background frequency of organism in microbiology databases
e) Notify ICPs for full chart review
f) Notify MD/nurse manager of unit/service
2) What is your level of concern? Medium
View Patient Details for this Alert
3) After reviewing the limited electronic data, what would you do next?
a) Disregard
b) Notify ICPs for increased awareness
c) Assess background frequency of organism in microbiology databases
d) Notify ICPs for full chart review
e) Notify MD/nurse manager of unit/service
4) After reviewing the limited electronic data, what is your level of concern? Very high
Close

Survey Concordance: Level of Concern

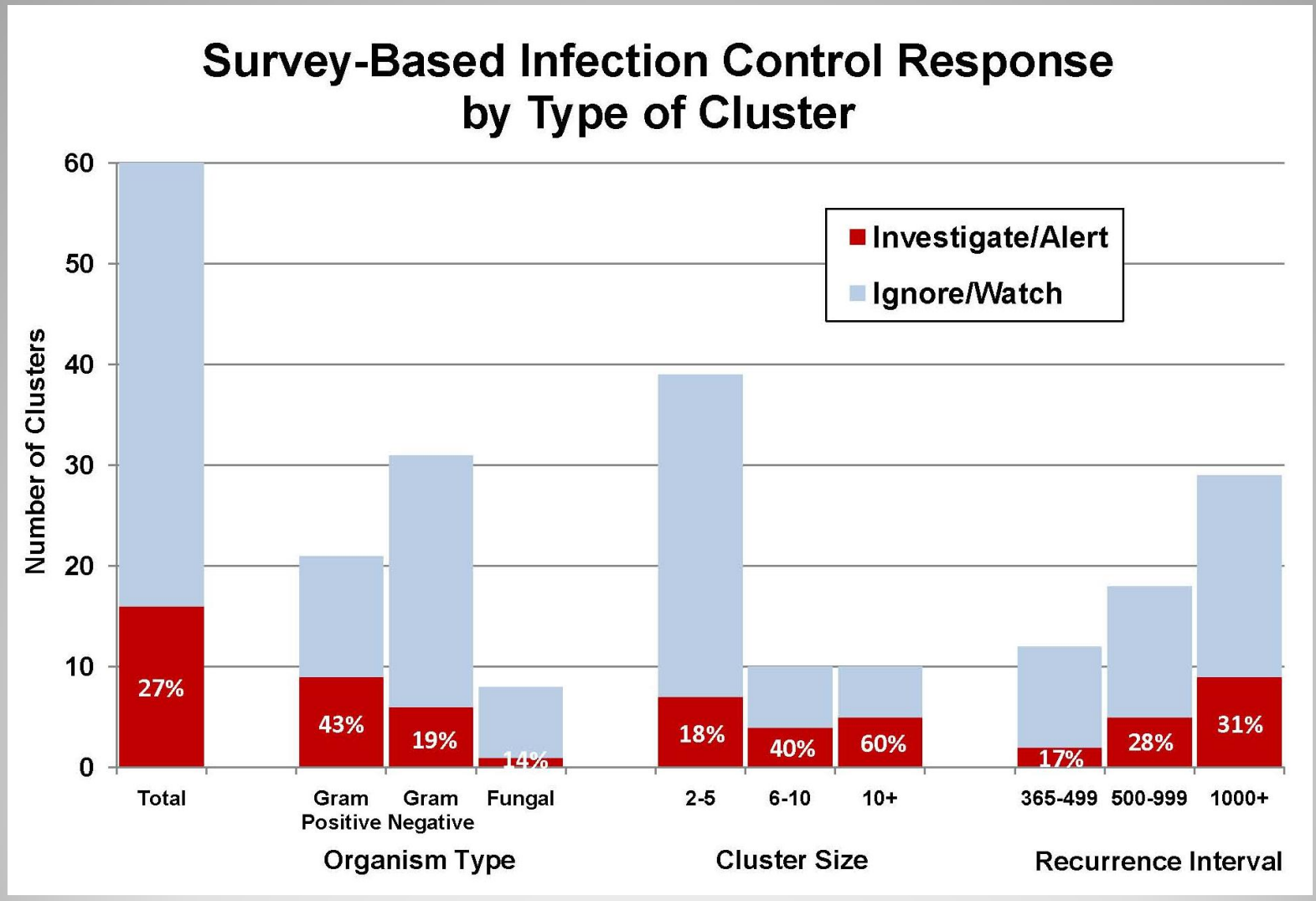
- 2 Hospital Epidemiologists
- Simulated daily evaluation across 6 Years
- 51 clusters, all deemed of interest
- **Level of Concern:** 86% concordance

MD1\2	Low	Med.	High
Low	33	2	1
Med.	1	1	0
High	1	2	10

Survey Concordance: Action taken

- **Action:** 82% concordance

MD1\2	Wait	Investigate	Unit ALERT
Wait	32	4	0
Investigate	1	0	2
Unit ALERT	1	1	10


Survey-Based Infection Control Response by Type of Cluster
Number of Clusters
60
50
40
30
20
10
0
Investigate/Alert
Ignore/Watch
27%
43%
19%
14%
18%
40%
60%
17%
28%
31%
Total
Gram Positive
Gram Negative
Fungal
2-5
6-10
10+
365-499
500-999
1000+
Organism Type
Cluster Size
Recurrence Interval

Comparison to Rule-Based Outbreaks

- Cluster-Based Rules
  - 3 cases in same unit within 2 weeks
  - For MRSA, “cluster alerts” were increasing as prevalence was rising. Some units were on alert for a year or more
  - Need statistical basis

W-S Algorithm vs IC 3-in-2wk MRSA Surveillance

	Infection Control Detection				WHONET-SatScan Detection				Dual Detection
	Clusters (N)	Cases (Mean)	Mean Duration (Days)	Cluster Type	Clusters (N)	Cases (Mean)	Mean Duration (Days)	Cluster Type	Clusters (N)
2002	14	10.8	96.5	Ward	1	14	67.0	Antibiotic Profile	0
2003	11	11.1	100.3	Ward	0	0	0.0	--	0
2004	18	6.9	65.3	Ward	1	8	54.0	Ward	1
2005	18	5.9	52.4	Ward	3	3.7	8.3	Ward, Ward/Service, Antibiotic Profile	0
2006	12	4.9	48.0	Ward	2	4	6.0	Service, Antibiotic Profile	0
5-Year Total	73				7				1
Annual mean	14.6	7.9	72.5		1.4	5.9	27.1		0.2
Annual median	14	6.9	65.3		1.0	4.0	8.3		0

W-S Algorithm vs IC 3-in-2wk VRE Surveillance

	Infection Control Detection				WHONET-SatScan Detection				Dual Detection
	Clusters (N)	Cases (Mean)	Mean Duration (Days)	Cluster Type	Clusters (N)	Cases (Mean)	Mean Duration (Days)	Cluster Type	Clusters (N)
2002	15	7.6	71.2	Ward	2	5.5	43.0	Antibiotic Profile	0
2003	12	6.4	62.8	Ward	1	4.0	18.0	Antibiotic Profile	0
2004	20	8.2	74.1	Ward	1	2.0	17.0	Antibiotic Profile	0
2005	18	7.2	69.1	Ward	0	0	0	--	0
2006	22	6.0	58.3	Ward	0	0	0	--	0
5-Year Total	87				4				0
Annual mean	17.4	7.1	67.1		0.8	2.3	15.6		0
Annual median	18	7.2	69.1		1	2	17		0

WHONET-SaTScan for Hospital Outbreaks

- Pilot test suggests
  - Reasonable number of alerts
  - Expands surveillance capability
  - Accurate detection of major clusters
- Discordance with empiric IC detection rules suggests resources may be better directed at clusters less likely to represent chance phenomenon
- Broader real-time assessments needed

Next Steps

- Develop user-friendly interface
- Expand evaluation to larger number of community hospitals
- Enhance algorithm
  - Evaluate effect of screening
  - Look for additional resistance patterns

Hospital Clusters Investigative Team

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