Using Modern Technology to Surveil, Monitor, and Diagnose Infectious Disease

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Agenda

- Surveillance
- History
- CDC's Traditional Approaches
- Digitally-based Systems
- Biosensor Program and NSSP
- Influenza
- Using RADTs with Wireless Capability for Surveillance
- Password-enable User Access to Transmitted Data
- Mobile App
- Comparison of RADT Performance to Dept. Of Health PCR
- RADT Use for Surveillance
- Future
- Conclusion

Notice

Influenza has traditionally been considered a model system for surveillance and modeling.

For this reason, I will use influenza predominantly as the example for discussing the development and use of quickly changing surveillance technology.

Simonsen, L. et alia. J. Infect. Dis. 214 (suppl 4): S380-S385.


Surveillance

Public Health Infectious Disease Surveillance Goals

- Provide meaningful, actionable information on circulating pathogens
- Do so in a manner that is timely and can facilitate public health intervention

Surveillance

- **Important attributes**
  - Demographic information
  - Representative of population
  - Should be representative of special or geographic settings
  - Clinical information quality (severity; recovery time; treatment)
  - Epidemiology
  - Assays' qualities (sensitivity and specificity and availability)
  - Validation of outputs (often historical)
  - Timeliness (close to real-time?)
  - Cost

Temte, J. et alia. "Real Time Influenza Surveillance in Primary Care"
J. Am. Board of Fam. Med., vol. 30 (5) 615-623 (2017)
Simonsen, L. et alia. J. Infect. Dis. 214 (Suppl 4) S380-S385. (2016)

Surveillance

- **Traditional Weaknesses**
  - Dependent on sentinel site detection (voluntary)
  - Dependent on Laboratory Reporting (not standardized; not timely)
  - Often dependent, as well, on clinical observations
  - Shortcoming of mechanistic tools specificity (e.g. Google Flu Trends)
  - Inadequate dissemination of observations
  - Timeliness is the number one short coming.

J. Temte et alia. "Real Time Influenza Surveillance in Primary Care"
JABFM, vol. 30 (5) 615-623 (2017)

Surveillance Utility and Applications

1. Helps public health officials prepare for unusual disease activity
2. Promotes timely vaccination campaigns
3. Improce risk assessments
4. Stimulates hospital and laboratory human resource planning
5. Triggers hospital and laboratory materials resource assessments
6. Enables issuance of warnings and educational notices for public
7. Facilitates pharmacy resource planning and allocations
8. Forecast time of arrival and geographic spread
9. Predict surge demand
10. Access to specimens for antigenic and molecular characterization and vaccine planning, as well as capabilities of existing diagnostic assays.

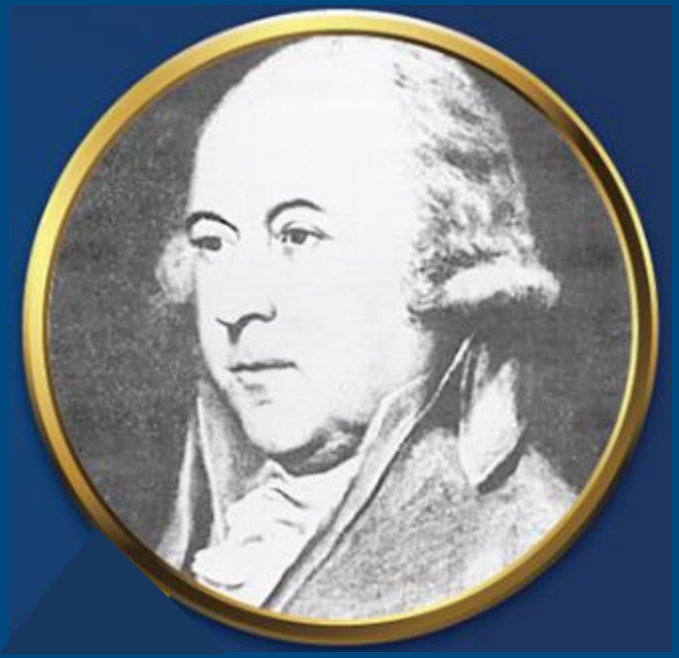
Yang et al. BMC Infectious Diseases (2017) 17:332
From: Nancy Cox, Ph.D., CDC, Options IX for Control of Influenza.
Walsh, M. et alia. U.S. Pharmacist 42 (4): 32-36. 2017

U.S. History

United States Public Health Service

1798

John Adams, the second president of the United States, signed into law the "Act for the Relief of Sick and Disabled Seamen." A year later, Congress extended the Act to cover every officer and sailor in the U.S. Navy. The Act led to the gradual creation of a network of marine hospitals along coastal and inland waterways.



President John Adams

https://www.usphs.gov/aboutus/history.aspx

U.S PHS
Public Health Service

History

Founded: 1798

Original mission:

a. Protecting against spread of disease by sailors from foreign ports
b. Checking and maintaining health of immigrants to our country

Restructured:

a. 1944, 1953, and became division of HHS in 1979

Mission today:

a. Protect, promote, and advance the health and safety of the United States
b. Responsible for NIH, CDC, FDA, HRSA, AHRQ, BARDA, ASPR et alia

Origins of
Food & Drug Administration

Harvey Wiley

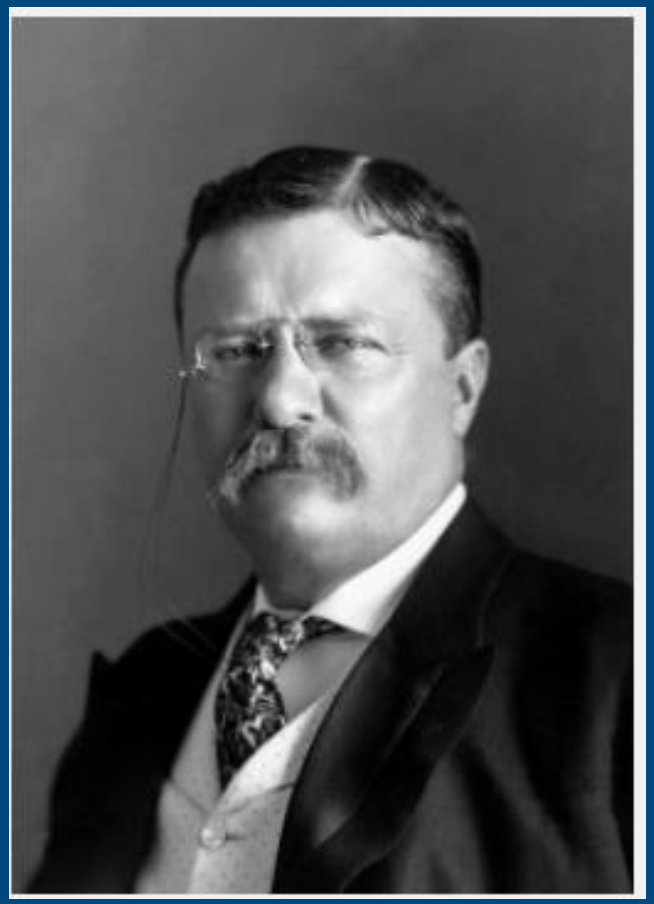
Division of Chemistry
Dept. of Agriculture
1887 to 1902

1913 Movie Poster

Upton Sinclair's Novel
"The Jungle"
Published in 1906

Government in Action

President Theodore Roosevelt



Signed the Wiley Act aka Federal Food & Drug Act 1906

President Franklin Roosevelt

Signed the Food, Drug and Cosmetic Act 1938

FDA

Food and Drug Administration

History

Founded: 1906

Restructured:

a. 1927, 1940, 1953, and became division of HHS in 1980

Mission today:

a. Promote public health by assuring the safety, efficacy and security of human drugs, biological products, medical devices, our nation's food supply, cosmetics, and products that emit radiation.

b. Speed innovations to new medicines /devices that are safer and more effective

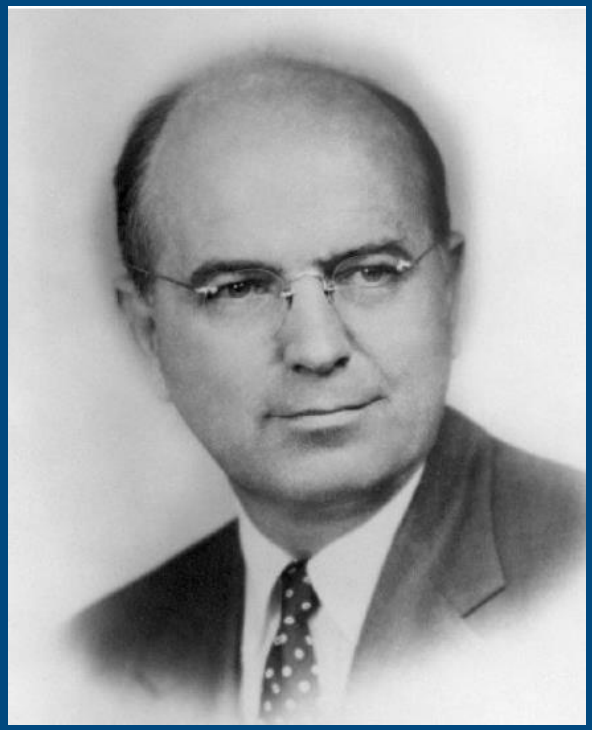
c. Provide public accurate, science-based information need to use medicines to improve health

d. Regulate manufacturing, marketing and distribution

e. Provide industry with predictable, consistent, transparent and efficient regulatory pathways

https://www.fda.gov/AboutFDA/WhatWeDo/History/Origin/ucm124403.htm

Joseph Mountin
1891-1952
Founder of CDC
1946



Alexander Langmuir
1910-1993
1st Epidemiologist at CDC
(first disease surveillance, 1949)

CDC

Centers for Disease Control and Prevention

History

Founded: on July 1, 1946

Original mission: field investigations, training, and control of communicable diseases.

Original Staff: mostly entomologists and engineers (400 people)

CDC

Centers for Disease Control and Prevention

TODAY

Mission: To protect Americans from health, safety and security threats—either of foreign or domestic origin , including chronic or acute disease human error, or deliberate attack

Strategic Areas:

1. Support State and Local health Depts.
2. Improve global health
3. Implement measures to decrease leading causes of death
4. Strengthen surveillance and epidemiology
5. Reform health policies

Staff: About 10,900 full time employees and ~3,000 consultants and part time support personnel.

https://www.cdc.gov/about/default.htm

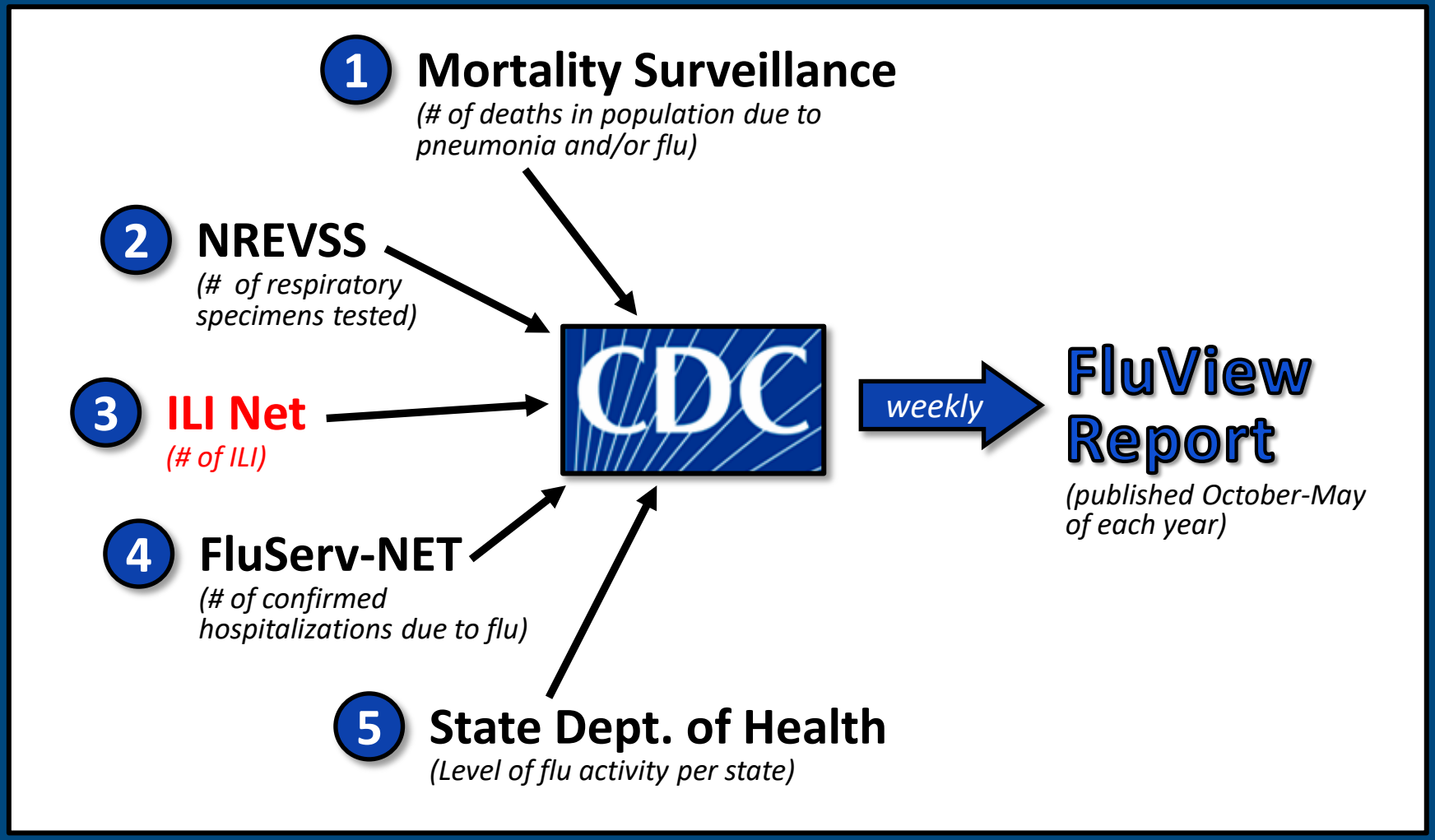
2017 Budgets

Agency	Budget
FDA	$5.1 billion
CDC	$7.0 billion
Total	$ 12.1 billion

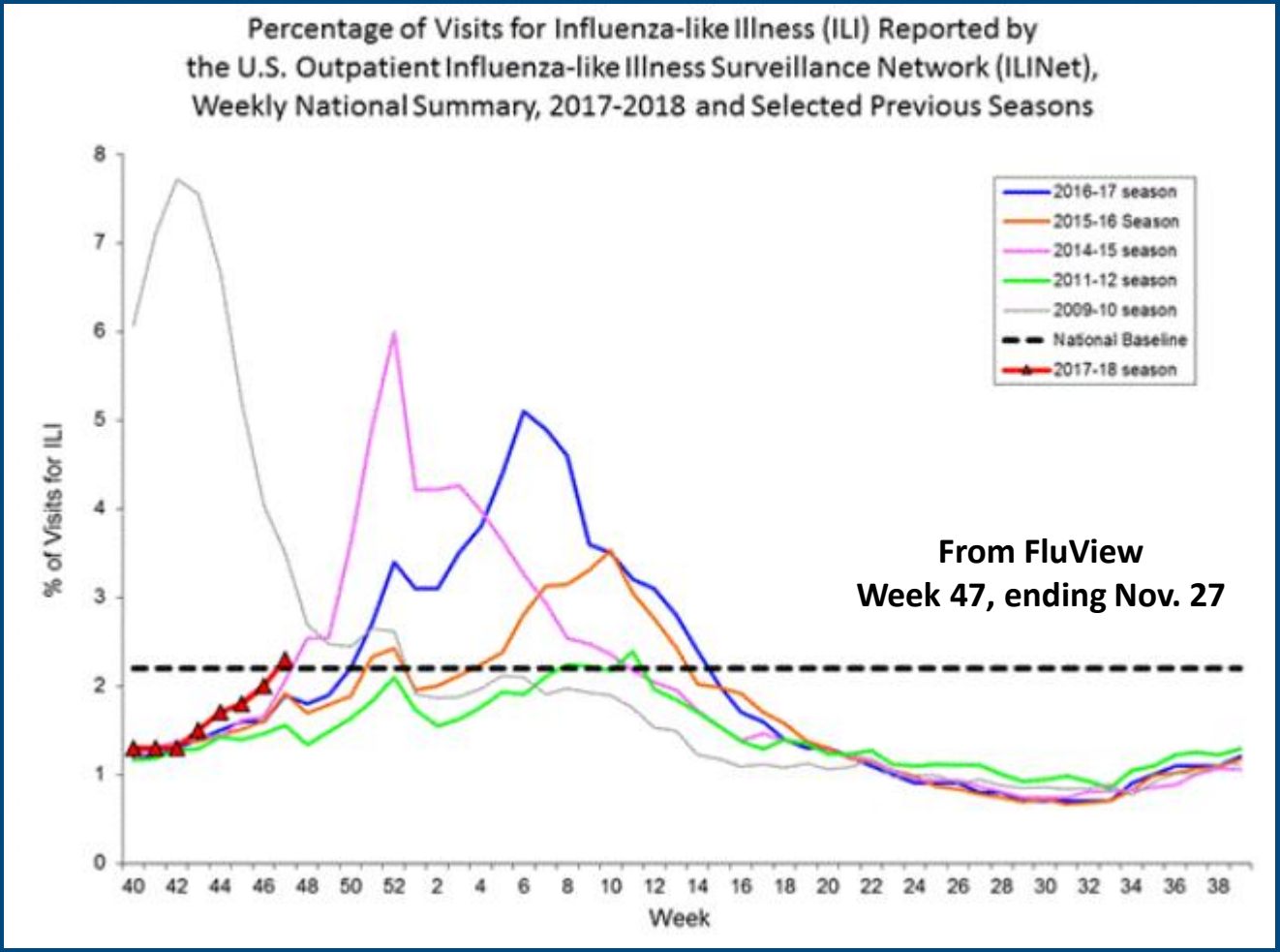
These programs represent a subset of activities aimed at helping to improve and secure good health for our citizens. And they all have very significant impact on surveillance and monitoring and diagnosis of our model disease—influenza.

CDC's Traditional Programs

Overview of Influenza Surveillance in the United States



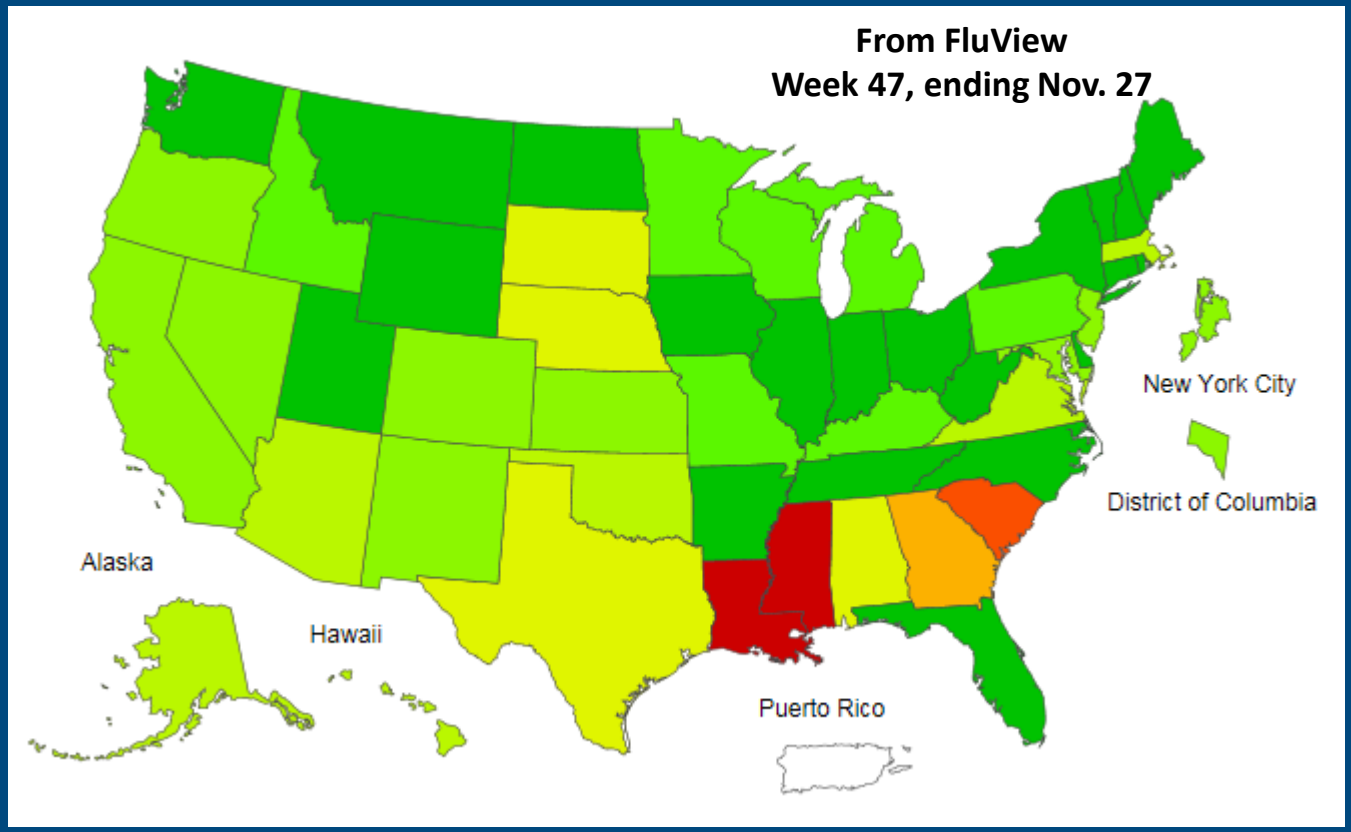
CDC: Outpatient Influenza-like Illness (ILI) Surveillance



"The number of specimens tested and % positive rate vary by region and season based on different testing practices….therefore it is not appropriate to compare magnitude of positivity rates or the number of positive specimens between regions or seasons."

CDC: Outpatient Influenza-like Illness (ILI) Surveillance

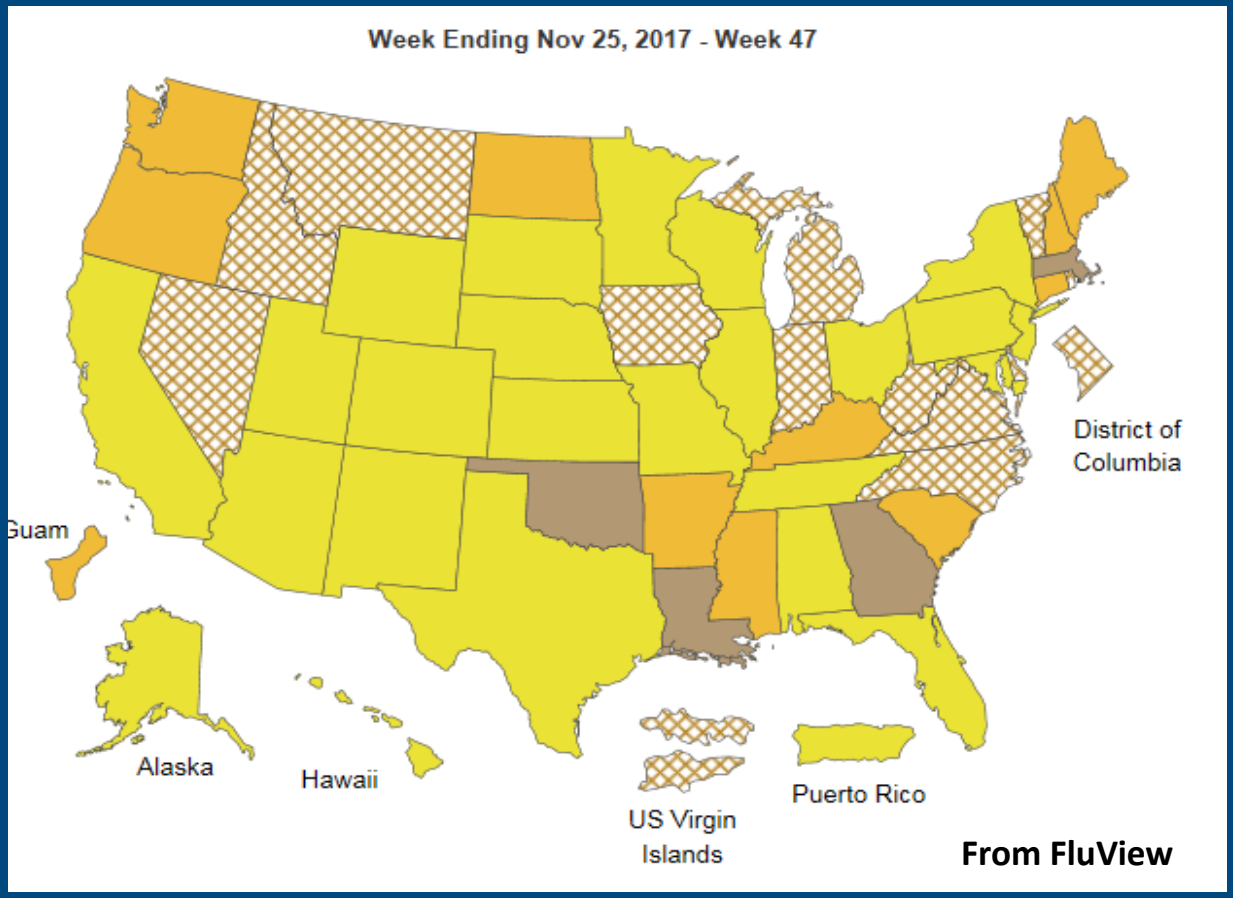
ILI-Net State Activity Indicator Map



Based on the number of outpatient visits to health care because of Influenza-like illness (ILI). "It does not measure extent of geographic spread within a state" and can be influenced by high levels in one city. Region to region comparisons are only rough estimates.

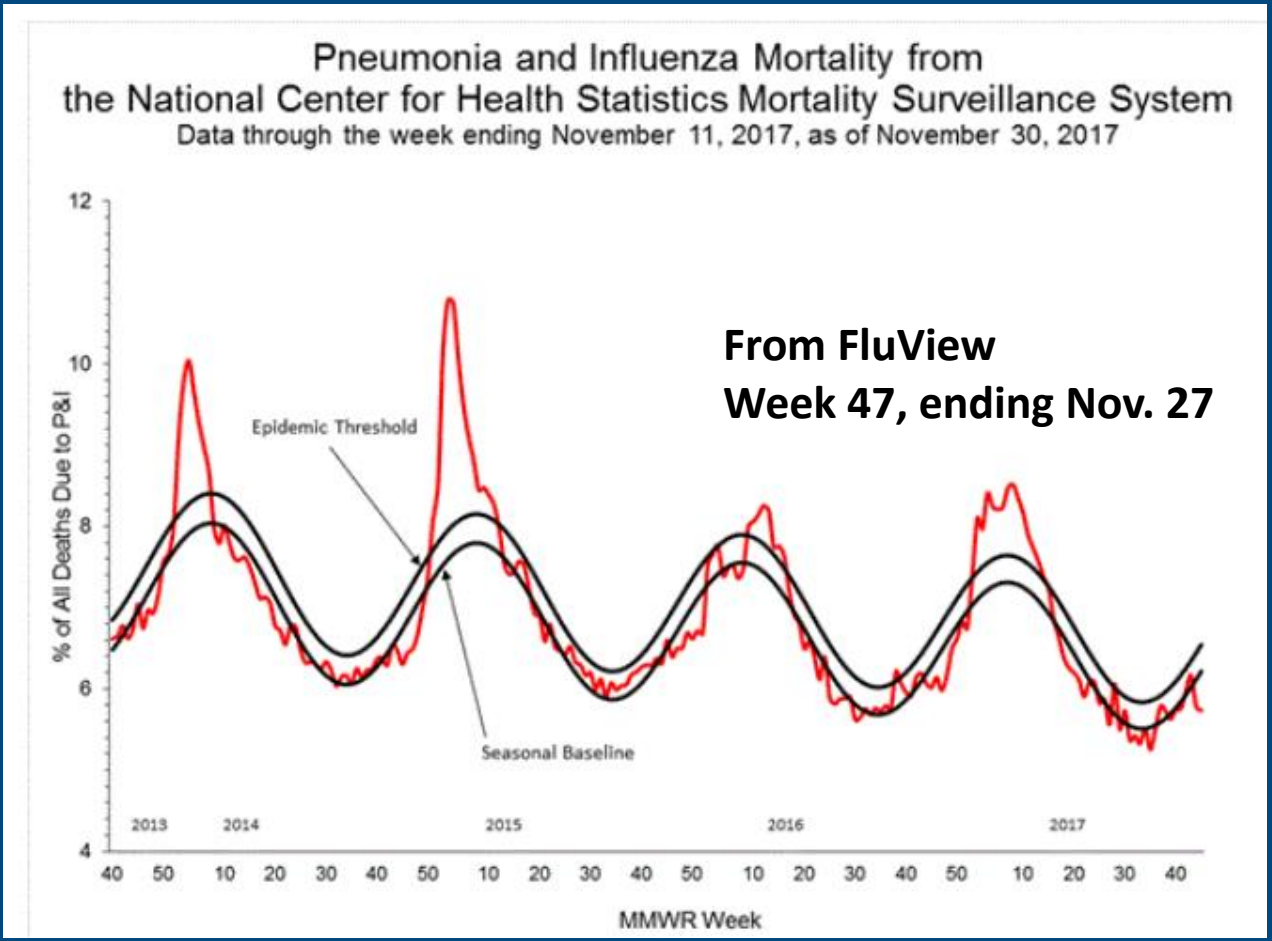
CDC: Outpatient Influenza-like Illness (ILI) Surveillance

Geographic Spread as Assessed by State and Territorial Epidemiologists



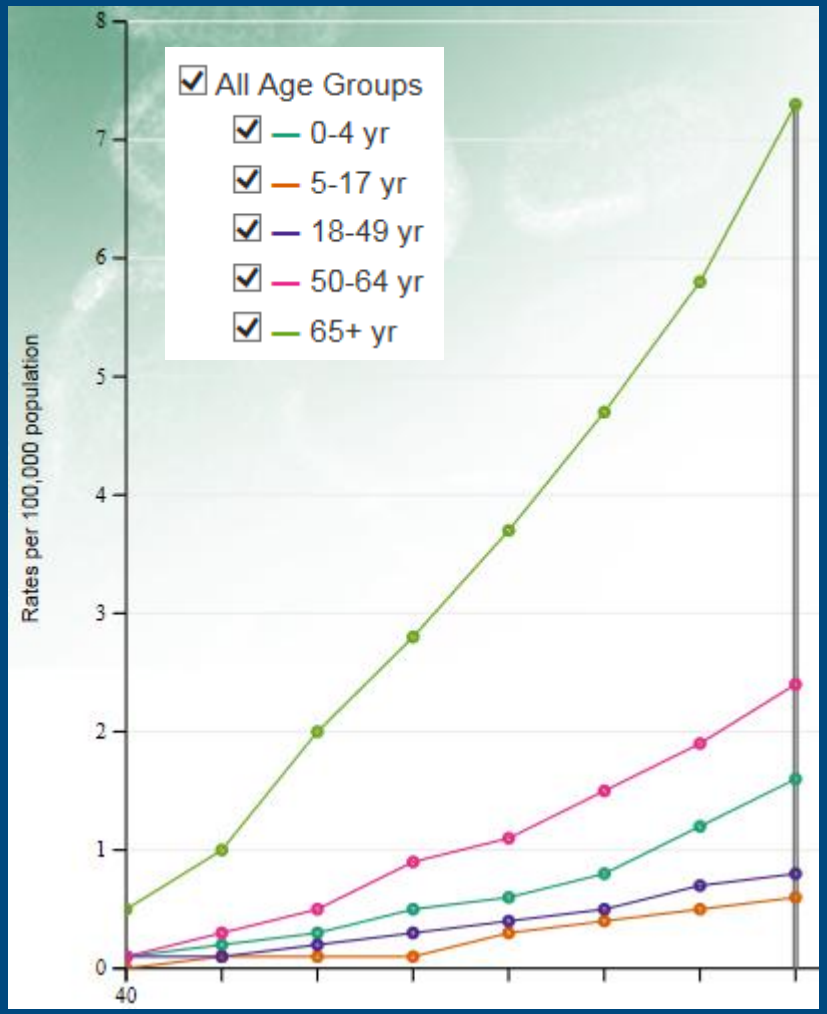
Data from state Depts. of Health are comprised of ILI patient visits to healthcare facilities and/or laboratory confirmed cases of influenza. The programs for each state are not standardized and vary significantly from state to state.

Pneumonia and Influenza Mortality Surveillance



"Based on National Center for Health Statistics mortality surveillance data available on Nov. 30th, 5.7% of deaths ending on Nov. 11 were due to P&I. This is below the epidemic threshold of 6.5%." There is a backlog of data requiring manual entry and this estimate is likely low.

CDC: Influenza Hospitalization Surveillance Network

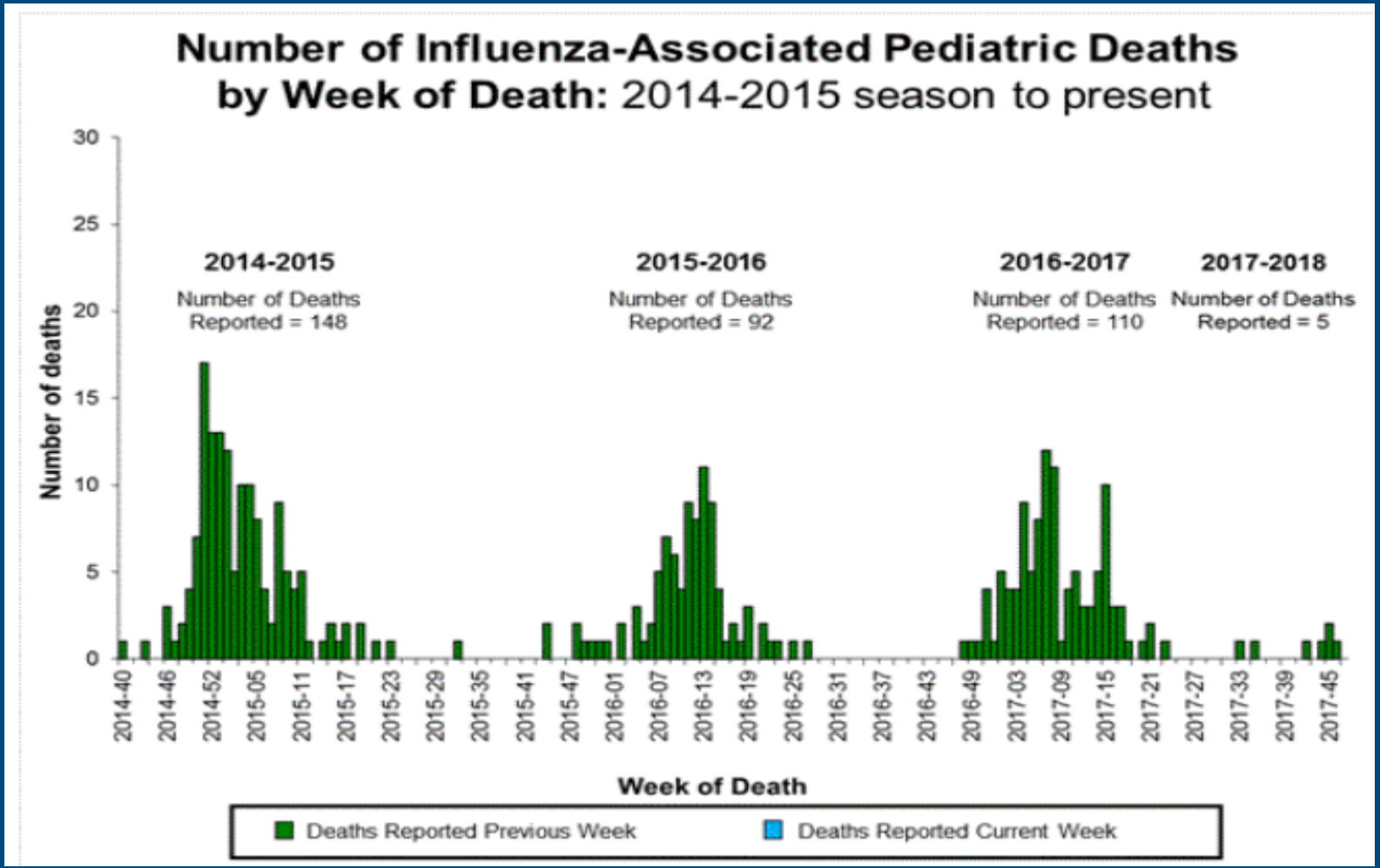


Rates are based on weekly-collected hospitalizations data that also report influenza positives by viral culture, DFA/IFA, PCR, and RIDT. "Rates are probably underestimated…"

From FluView
Week 47, ending Nov. 27

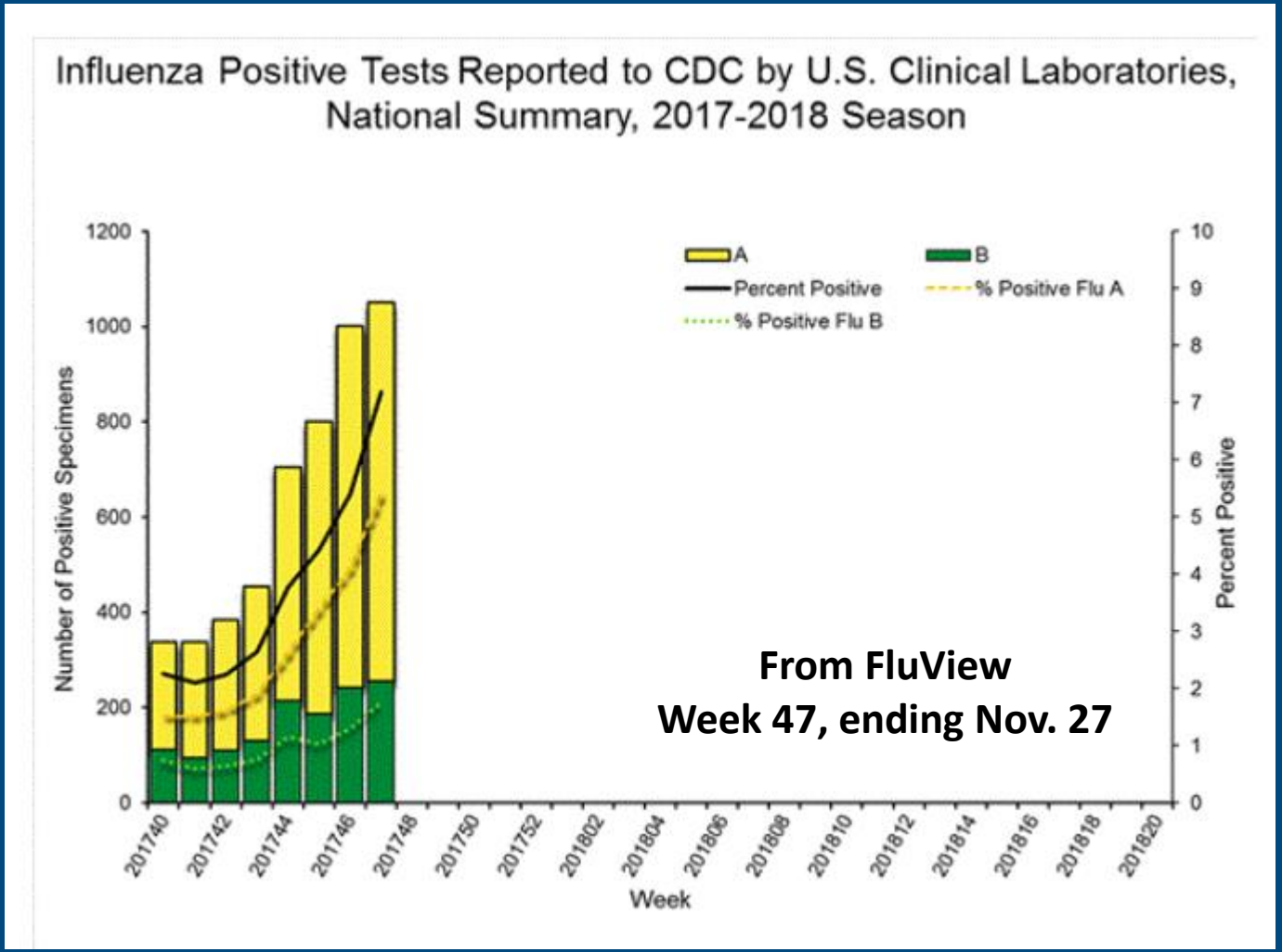
Based on data collected from only 13 States.

CDC: Influenza-Associated Pediatric Deaths



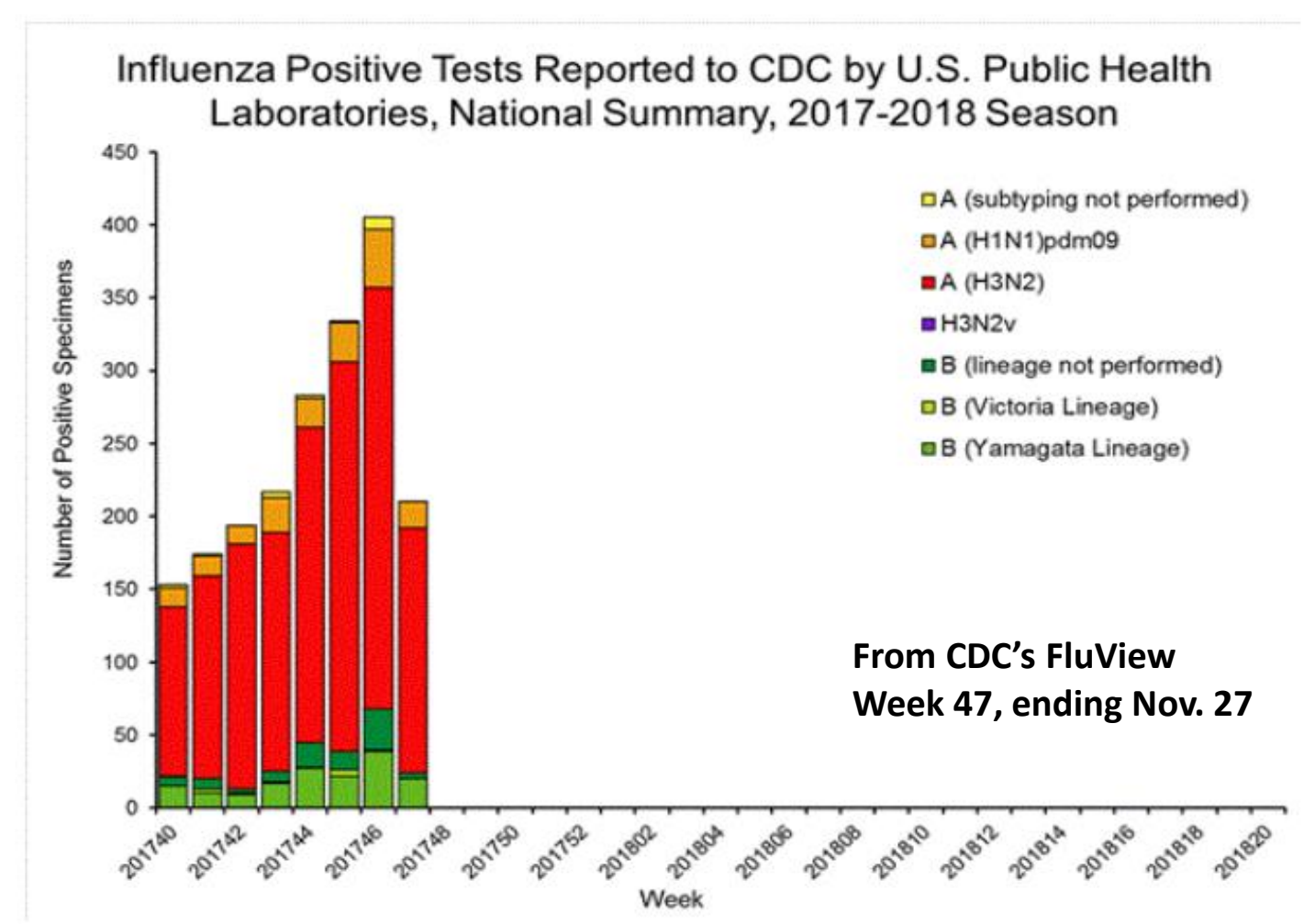
Similar data are not routinely presented for other high risk groups—pregnant, >65 yrs. of age, etc. in FluView.

CDC: U.S. Virologic Surveillance



"The percentage of positives is not shown because PHLs usually get samples that have already tested positive. The actual incidence of influenza and the actual percentage positive is not available".

CDC: U.S. Virologic Surveillance (cont'd.)



Detail about the types of circulating influenza types and strains is reliable. However, one cannot estimate actual positivity rate and prevalence in any region confidently.

U.S. CDC Surveillance Limitations

- Passive system with delayed reporting (often 1-3 weeks)
- Compliance (voluntary) and poor
- Lacks standardization
- Costs impair reporting
- Does not collect incidence data
- Limited feedback mechanisms
- Trends not linked to demographics
- Problems with connectivity
- Sentinel sites do not calculate % positives
- Broader geographical spread needed
- Faster turn around needed
- More graphics and mapping features desired
- Missing epidemiological information
- Influenza-like-illness is often NOT influenza
- Traditionally based on numbers of patients' clinical visits.
- Collecting information from clinical records takes time and resources.

New Approaches
Digitally-based Systems

Improving Data Access and Quality

1. CDC is expanding the use of laboratory results from State Departments of Health
   a. Results nearer to real-time
   b. Enhanced efforts to get state participation and standardized systems

2. Supporting FDA's reclassification of rapid antigen detection tests for influenza
   a. Improving the quality and clinical accuracy of RADTs for influenza (effective Jan. 12, 2018)
   b. Ensuring performance versus emerging viruses

Overcoming Shortcomings of Traditional Methods Digital Influenza Surveillance

Problem: traditional methods are slow, taking 1 to 3 weeks

Goal: The earlier the warning provided by surveillance, the sooner preventive and other control measures can be taken.

Digital disease surveillance: has been attempted and/or is being used to attempt to address this shortcoming.

Four categories of digitally-based systems:

1. Participatory Surveillance Systems
2. Internet News Data Systems
3. Search Query Systems
4. Social Media Systems

E. Nsoesie and J. Brownstein. Cell Host Microbe 2015 March11; 17(3) 275-278

Participatory Digital Surveillance Systems

Participatory Surveillance Systems

1. Consortium of registered members who voluntarily report how they feel; data are subsequently collated and disseminated to members, e.g. weekly.
2. Challenges: accuracy of reported data; lack of standardization; inadequate geographic coverage; reliability of participants.
3. Flu Near You is example.

Voluntary Participation
(you report how you've been feeling)

Crowdsourced Data
(thousands of participants per week)

Visualized Map
(thousands of participants per week)

Internet News Data Digital Surveillance Systems

Internet News Data Systems

1. Data procurement directly from Internet primarily with subsequent analyses to detect trends; analysis of data by time and geography; dissemination to public health and other entities
2. Challenges: unstructured sources of data complicate collation and analysis; huge amounts of unrelated data can hide important data
3. HealthMap is example

Online news aggregators, eyewitness reports, expert-curated discussions and validated official reports, to achieve a unified and comprehensive view of the current global status of disease.

Search Query Digital Surveillance Systems

Search Query Systems

1. Data procurement also directly from Internet, using key words and massive web data
2. Challenges: Key word changes can have profound effect; web user behavior between truly ill persons and those simply seeking information about a particular illness; requires frequent validations; specificity
3. Google Flu Trends is example.

Google Flu Trends is no longer publishing current estimates of Flu based on search patterns…Academic research groups interested in working with Google can approach them.

Social Media Digital Surveillance Systems

Social Media Systems

1. Based on individual reports of influenza or flu-like-illness, e.g. on Twitter, Facebook, and Google. Large amounts of data must be extracted and filtered and analyzed. Often use third party data as well, when available.
2. Challenges: The nature of the source of data introduces biases based on distribution across geographic location, age, race, and other demographics.
3. Sickweather is an example. It combines self-reported data as well as that extracted from social media systems.

"Sickweather scans social networks for indicators of illness, allowing you to check for the chance of sickness as easily as you can check for the chance of rain."

Limitations
Digital Surveillance Systems

Limitations

1. Differentiating signal from noise (specificity)
2. Biases due to representation of individuals in different locations or of different race, ethnicity, income, etc.
3. Differences between information and analysis of Internet-sourced data versus traditional, scientifically sound surveillance systems that are well-established (but need improvement)
4. Maintenance of privacy of individual's health data.
5. Paucity of published controlled studies

E. Nsoesie and J. Brownstein. Cell Host Microbe 2015 March11; 17(3) 275-278

Biosense Program and NSSP

CDC's BioSense Program

- **Launch**
  - Launched in 2003 in response to Public Health Security in Bioterrorism Preparedness Act of Congress in 2002
- **Goals**
  - Improve capabilities for near real-time information and situational awareness
  - Advance analytics for diagnostic data
  - Increase sharing of data between federal, state and local PH agencies
  - Promote standards and specifications to facilitate such integration

CDC's BioSense Program (Cont'd.)
NSSP

- **Name Change**
  - 2014, National Syndromic Surveillance Program (NSSP)
- **Status**
  - Over 4,000 hospitals report ED visit data
  - Represents 55% of all ED visits nationally
- **Renewed Goals**
  - Increase data availability and representativeness of ED visits regionally and nationally
  - Improve data quality
  - Facilitate use of data for situational awareness and response to hazardous events and disease outbreaks

Gould, D. et alia. Public Health Reports. Vol. 132 (Suppl 1) 7S-11S. 2017

Syndromic Data for NSSP

- **Patient Encounter Data**
  - Emergency departments
  - Urgent care centers
  - Ambulatory Care
  - In-patient Healthcare
  - Pharmacies
  - Laboratory Data
  - School and Business Absentee Data
  - Social Media
- **Use**
  - Monitored in near “real-time” as indicator of an event or disease outbreak
  - Information shared between public health agencies

www.cdc.nssp.gov

Influenza as a Model

Why?

Why Influenza?

United States

Deaths	**3-49K**
Hospitalization	**54-430K**
Cases/Year	**15-60 million**

Global Impact

250-500K	**Deaths**
3-5 million	**Severe Cases**
>700 million	**Cases/year**

- The overall annual costs for influenza in the United States ranges from $50 billion to $87 billion dollars per year.
- Direct costs alone exceed $10 billion/year.
- The virus undergoes antigenic drift constantly.
- The vaccines are only partially effective and must be remodeled and produced each year.
- A large percentage of our U.S. population is at high risk from influenza
- In 1918, 1957, 1968, and 2009 the virus underwent antigenic shift, causing pandemics, causing 766 thousands deaths in the U.S. alone.

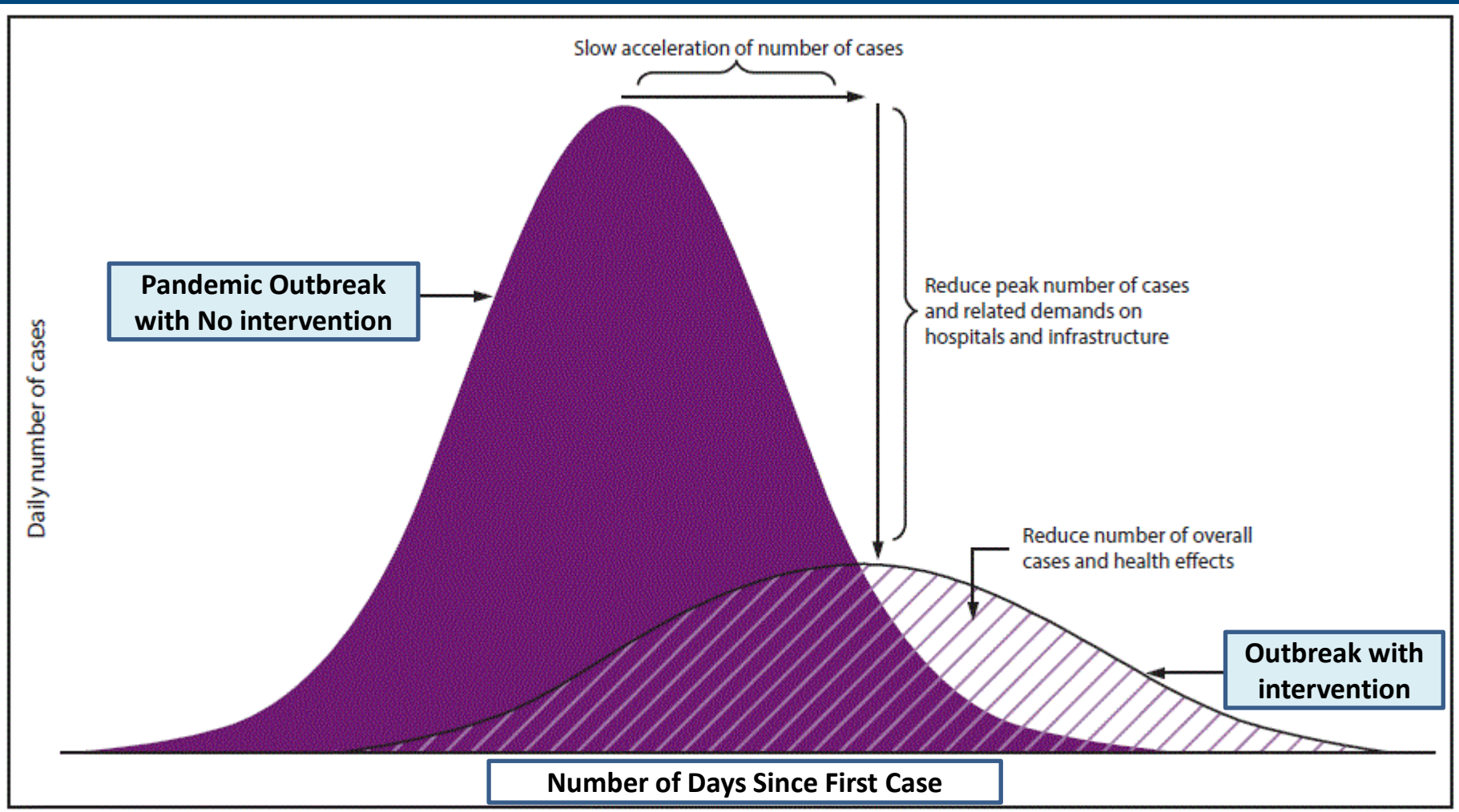
From Nancy Cox, Ph.D., CDC, Options IX for Control of Influenza.

Individuals at High Risk from Influenza

- Pregnancies/yr: 6,000,000
- Organ Transplants/yr: ~30,000
- Bone marrow transplants/yr: ~22,000
- Heart disease: 85.6 million
- Respiratory impairments (COPD and asthma) : 37.6 million
- Population > 65 years of age: 43 million
- Infants < 2 years of age: 8 million
- Diabetes and metabolic impairments: >>30 million
- American Indians and native Alaskans: 2.9 million
- Morbidly obese

This is a disease at need of the best possible surveillance..

Rational for early detection of Influenza



CDC. Community Mitigation Guidelines to Prevent Pandemic Influenza — United States, 2017. MMWR Recommendations and Reports 2017;66(1):1-32.

Using RADTs with Wireless Connectivity for Surveillance

RADT Data

The following several slides show the use of results obtained with a CLIA-waived immunofluorescence-based lateral flow assay.

The result interpretation is obtained with an FDA-cleared, CLIA-waived instrument within 3 to 15 minutes, depending on virus level.

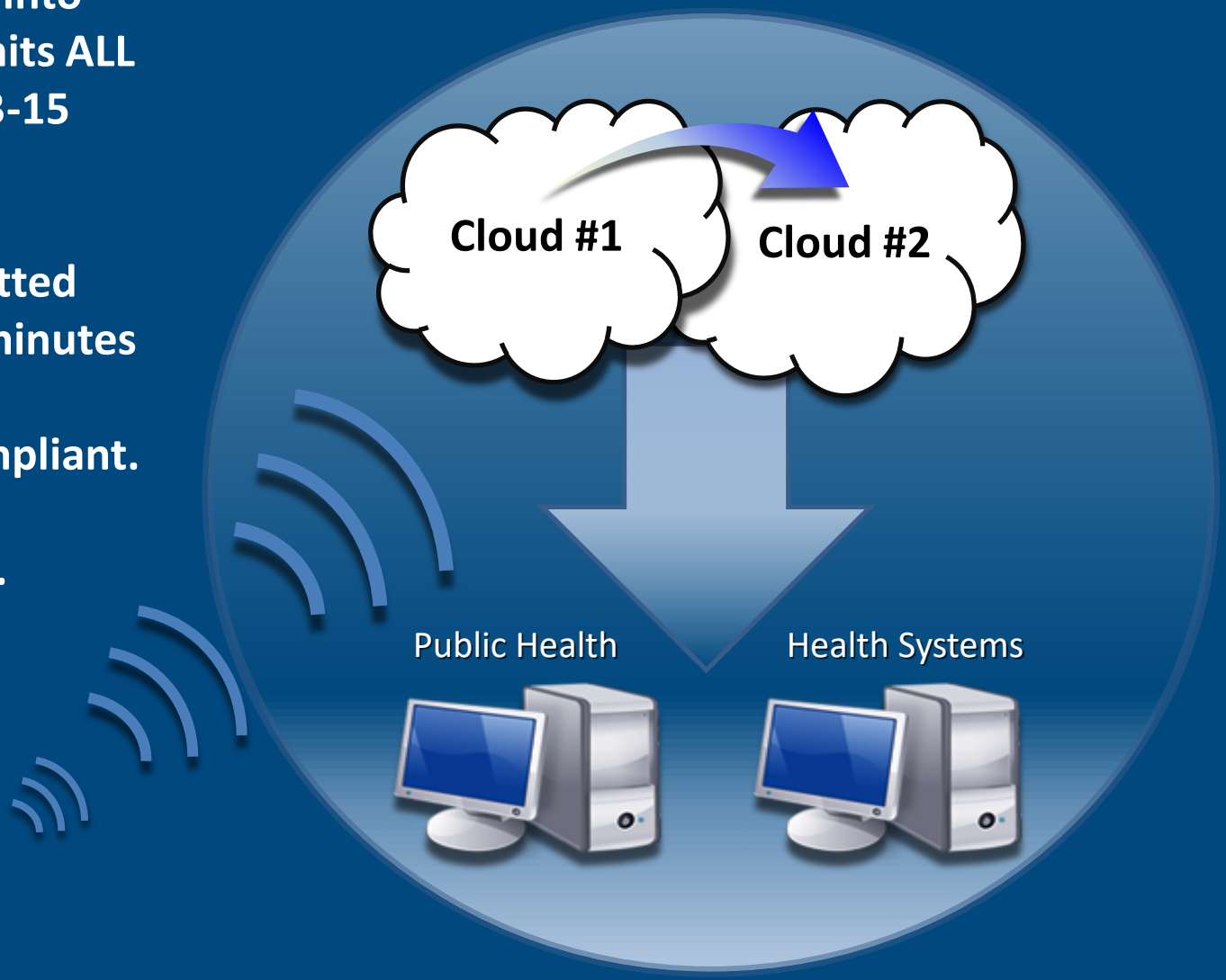
Interpretation is objective, automated, and can be wirelessly transmitted by an instrument.

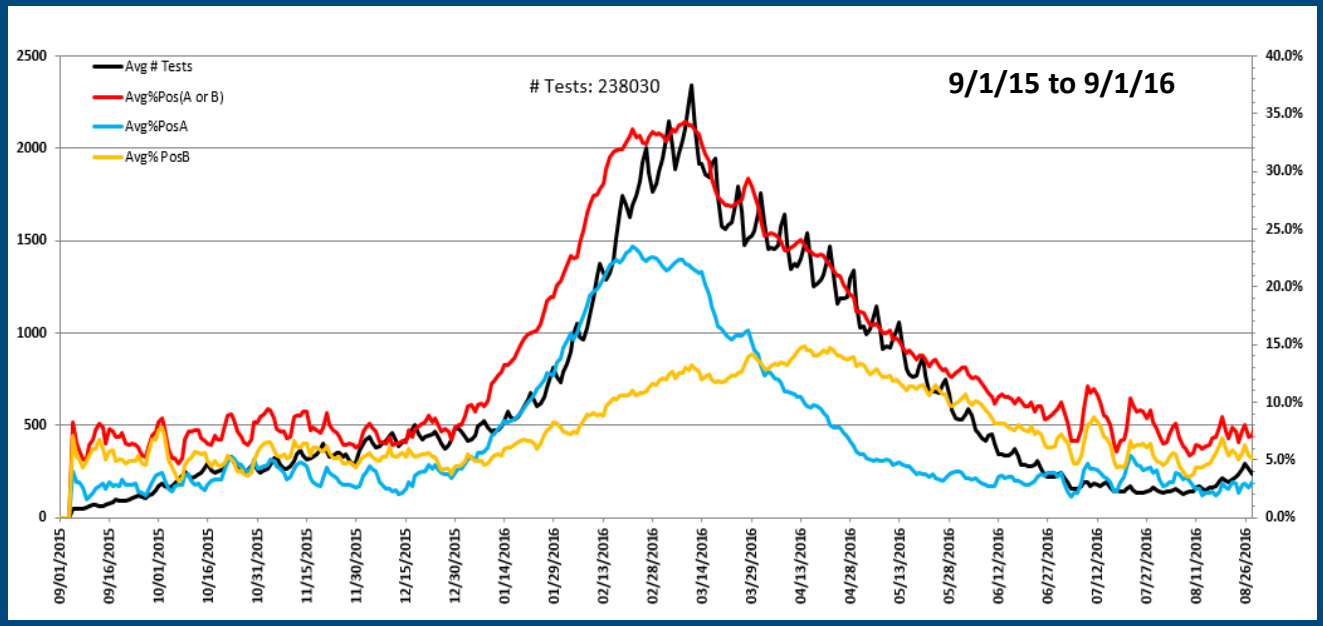
CLIA-waived lateral flow cassette is inserted into Analyzer. It transmits ALL test results within 3-15 minutes.

Results are transmitted within seconds to minutes

Data are HIPAA compliant.

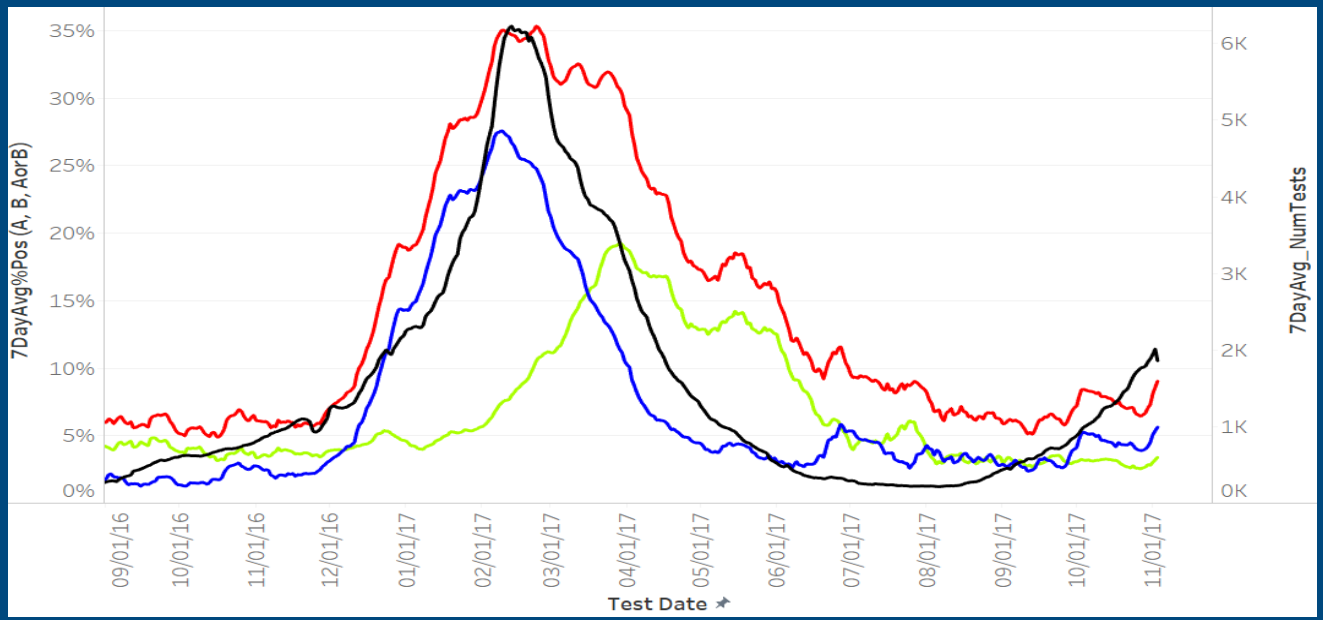
Data are encrypted.





2015-2016 season

238,000 patient results.. Peak positivity rate for A+B was March 7, 2016 at 34%.



2016 -2017 season

684,791 ILI patient results. Peaked February 9th at 35%.

This system has wirelessly conveyed results every night at midnight to CDC for over two years (>922,000 ILI patient results as of 9/1/17).

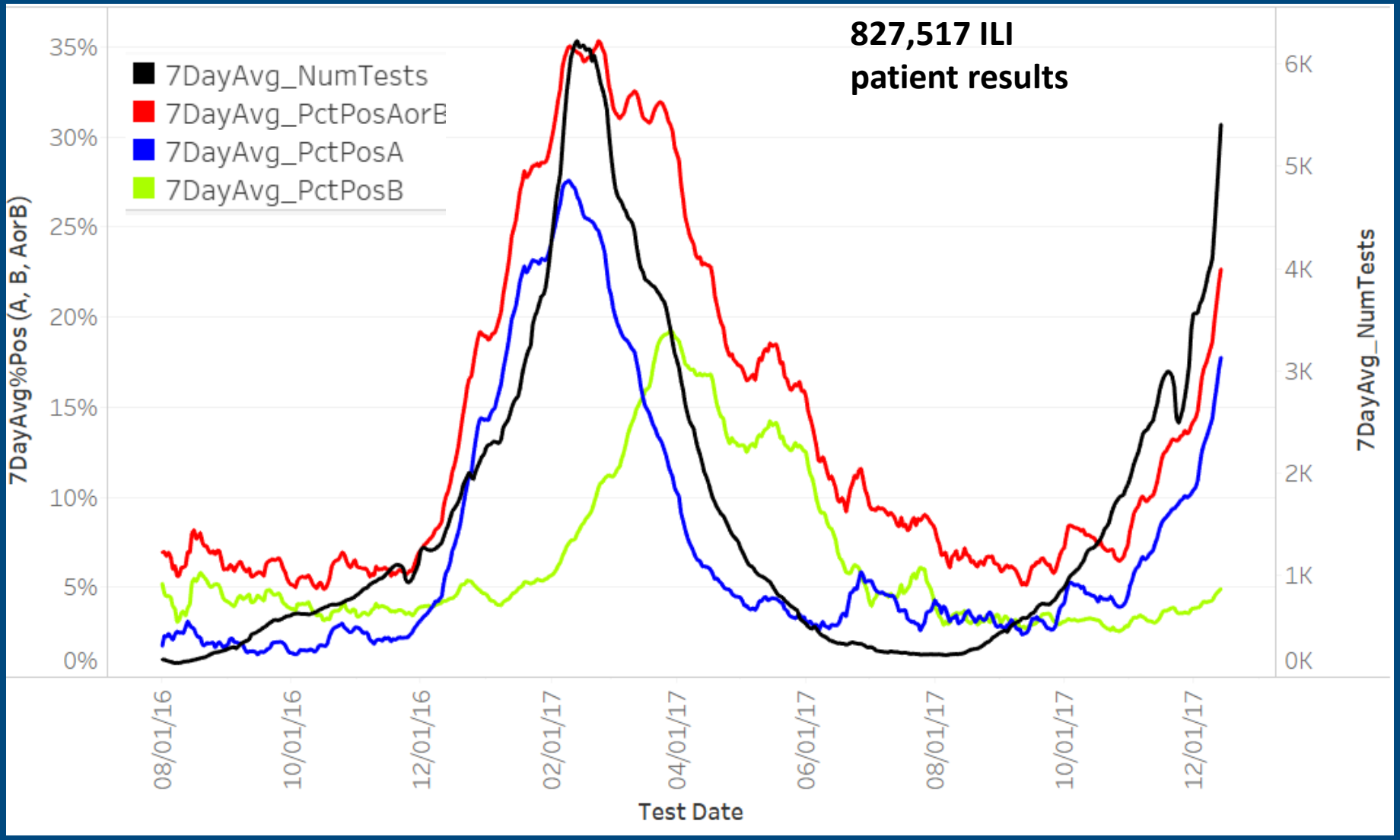
~4,500 Transmitting Systems

>18,500 instruments

12-14-17

USA Influenza Status

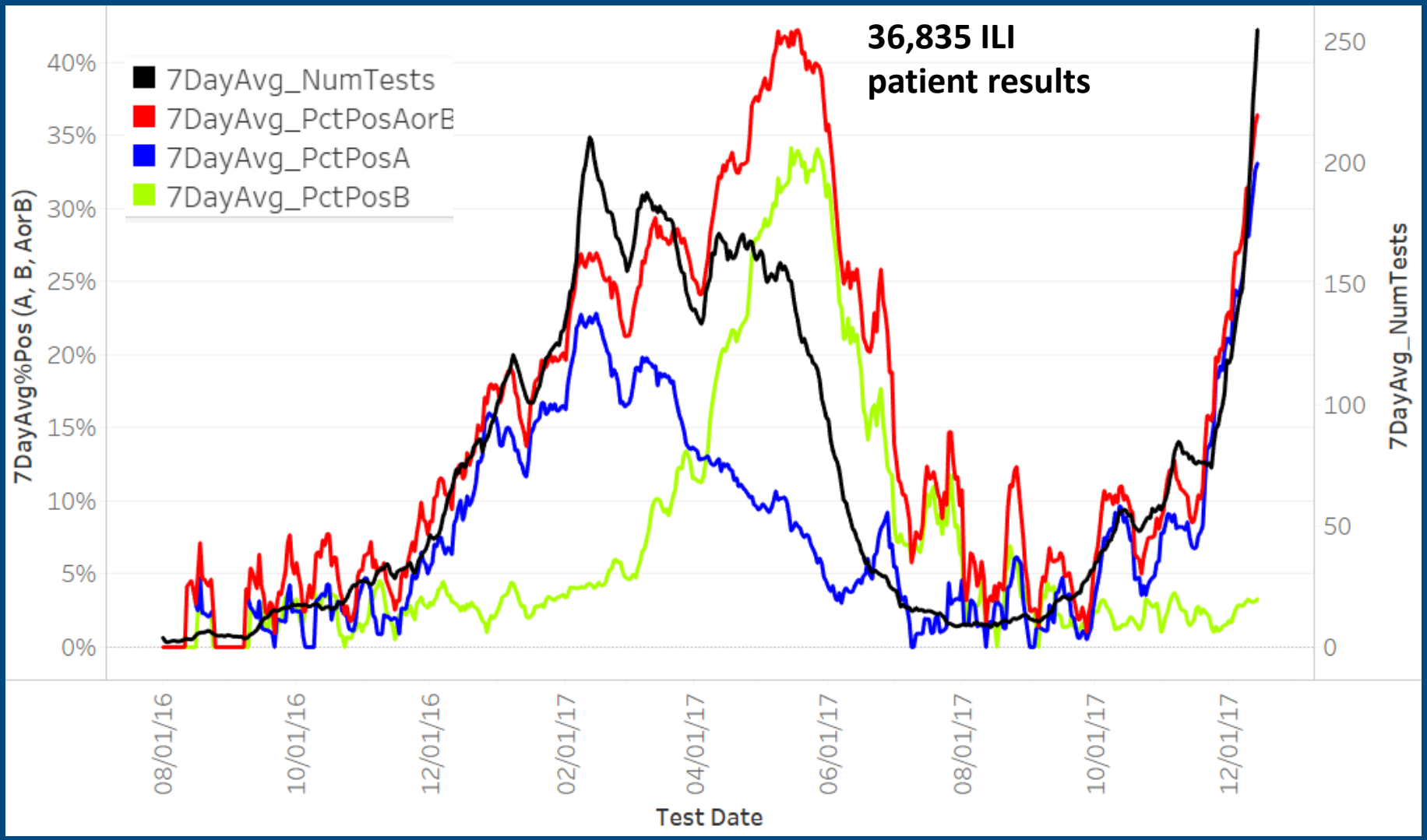
Sept. 1, 2016 to Dec. 16, 2017



Influenza positivity rate is 22.7% as of yesterday in the U.S.
5,410 patient results transmitted per day.

Arizona Influenza Status

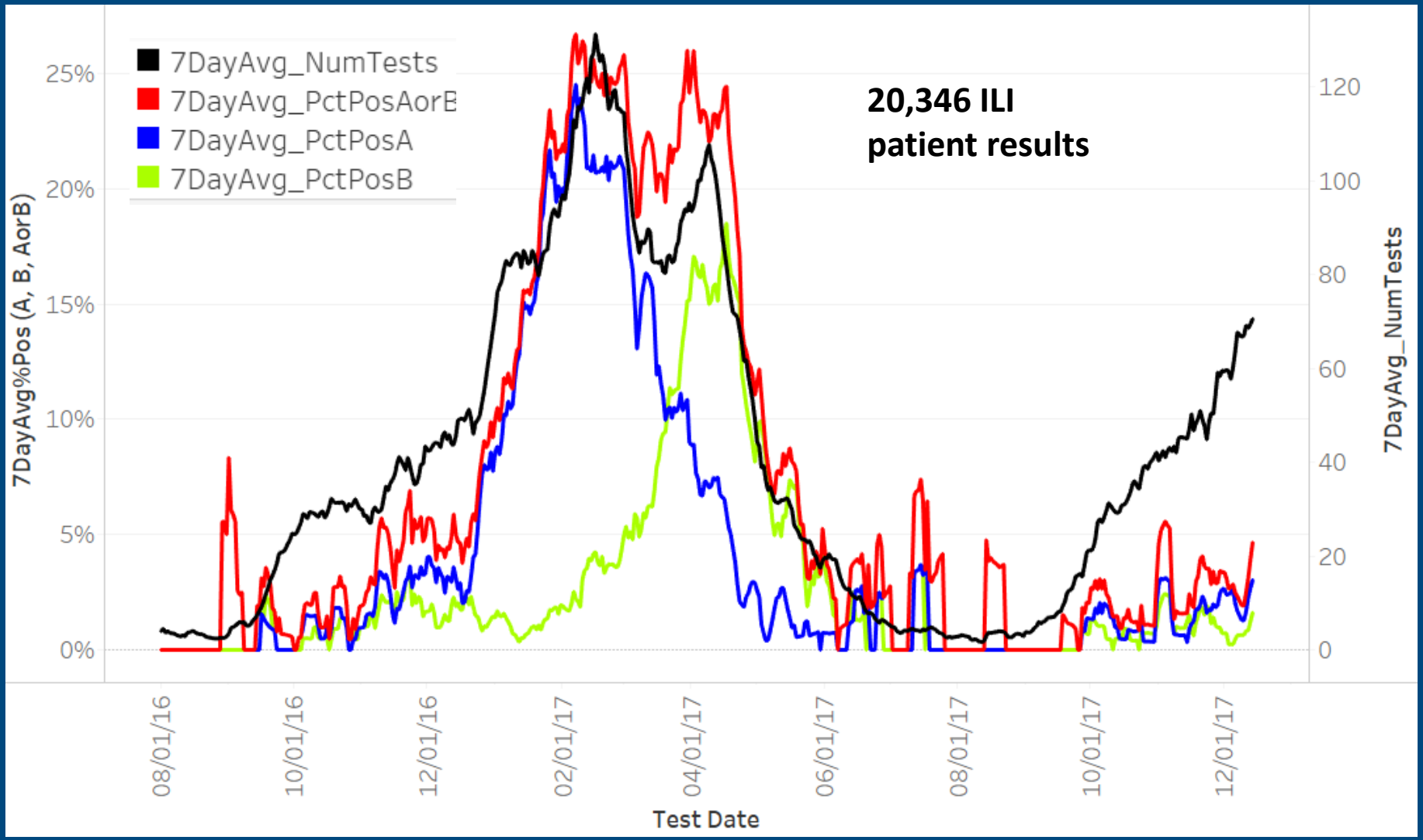
Sept. 1, 2016 to Dec. 16, 2017



Influenza A and B positivity rates are 33.1% and 3.3%, respectively!
255 tests transmitted per day. Strong onset!

Massachussets Influenza Status

Sept. 1, 2016 to Dec. 16, 2017



Influenza positivity rates is only 4.7%. 71 tests/day.
No Influenza YET.

Password-Enabled User Access to Pre-programmed Analyses of Wirelessly Transmitted Data

User's Specific Access to Transmitted Data

- Website confidential, password-enabled access to an organization's data.
- Analyzes facility's or facilities' test results using pre-programmed analytics and graphic capabilities.
- Allows monitoring trend in one's community, county, state and nation.
- Website data are updated automatically on a daily basis.
- These are near real-time data based on actual test results—not on physician assessments that are based on signs and symptoms.
- Only HIPAA compliant, patient de-identified information is
- Data are available within seconds or minutes via a private, confidential password.

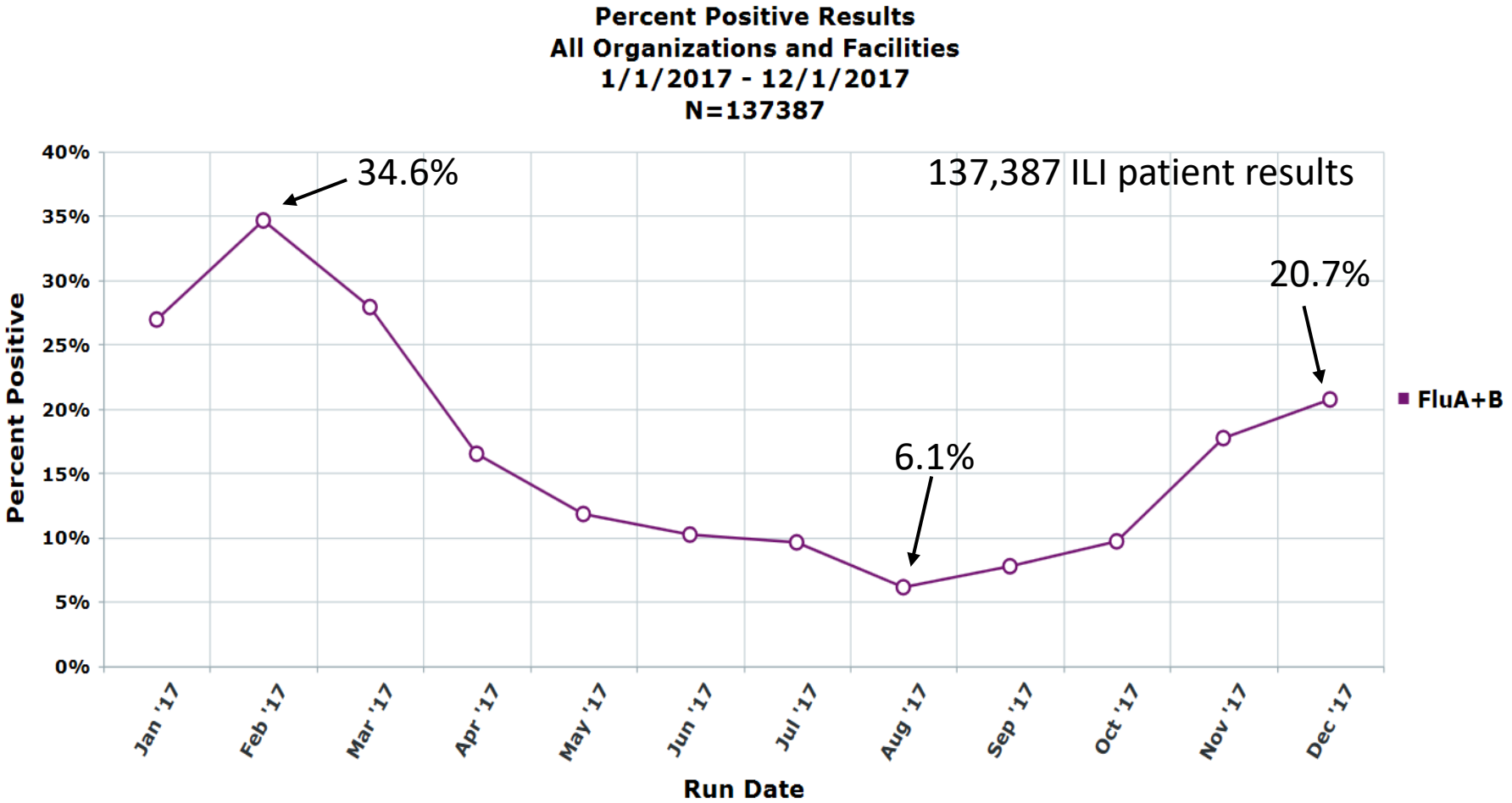
User Selects
Pre-programmed Analyses, Charts, and Graphs

Patients by Assay
Patients by Facility & Assay
Patients by Facility & Result
Patients by Result
Patient Result Trends
Percent Positive Results
Quality Control Report
Test Volume by Type (Influenza, RSV, Strep, etc.)
Regional Mapping

Results are automatically update daily at midnight.

Texas: Influenza Status by (By MONTH)

1-1-17 to 12-1-17



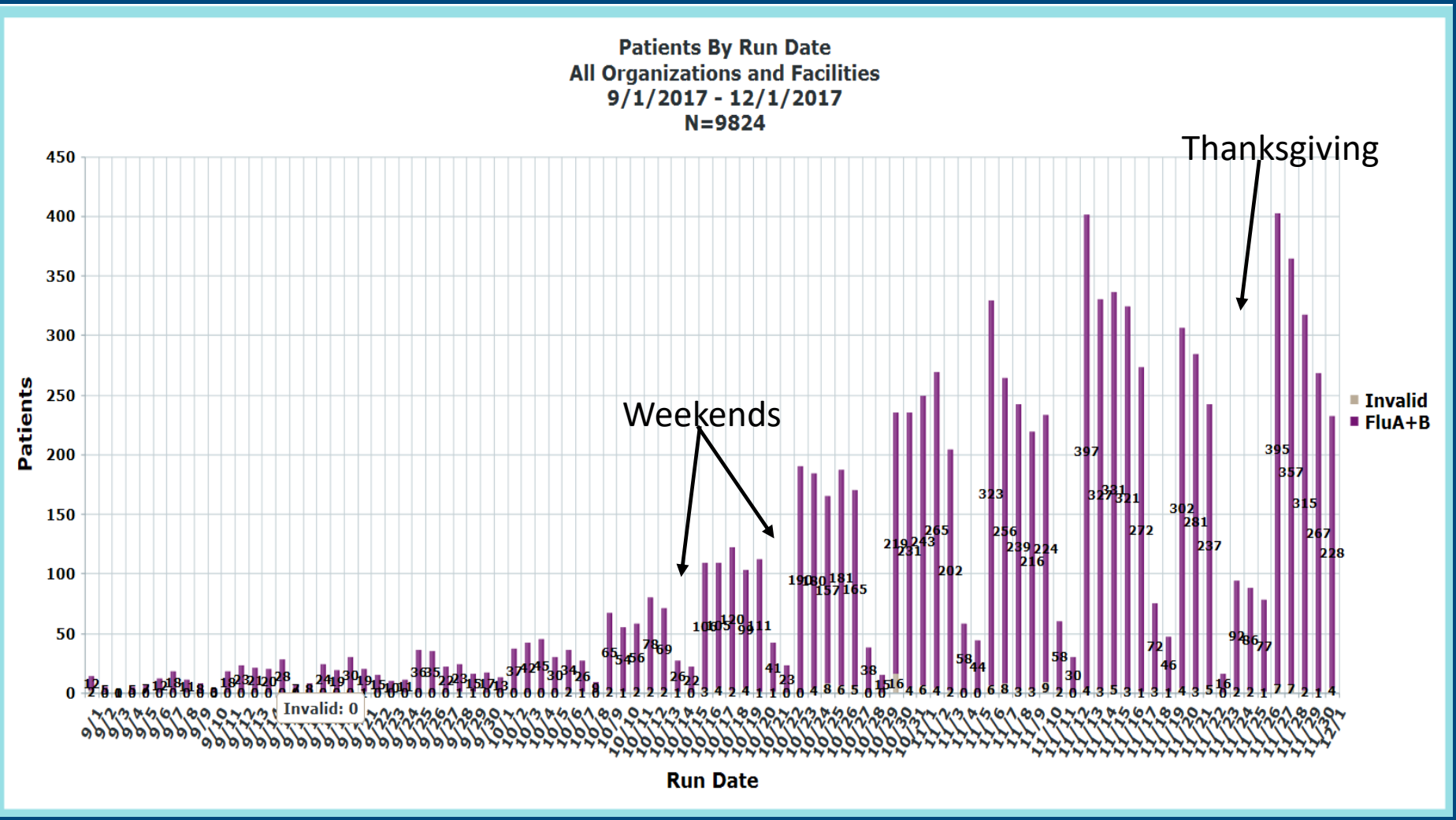
In ten seconds, I was able to make the request and get the information above.

The positivity rate has ramped quickly since October 15th

Texas: Influenza Status

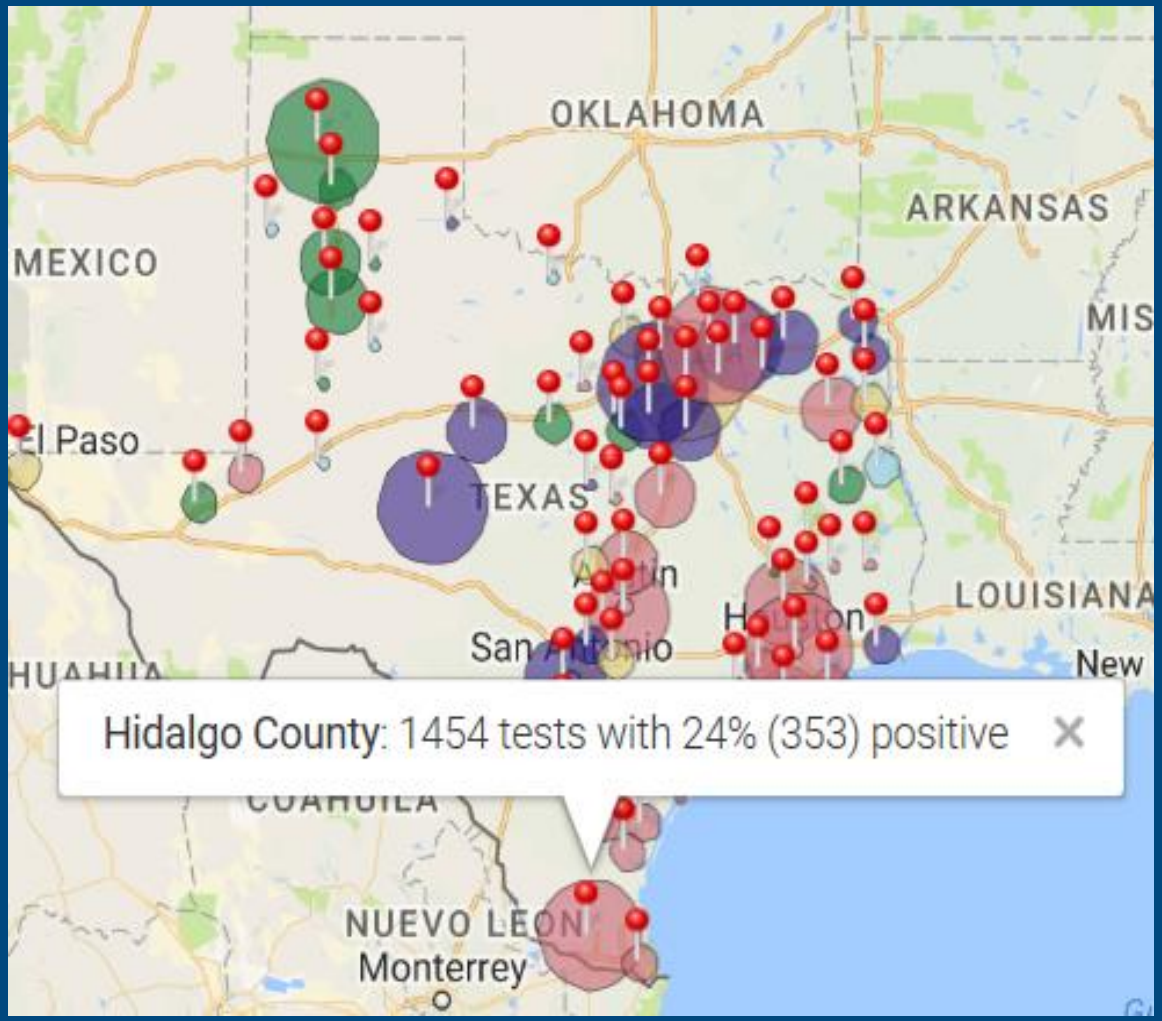
Patients By Run Date (By DAY)

9-1-17 to 12-1-17



Tests per day can be viewed historically and give advice on resource planning.

Texas: Influenza Status by Mapping Feature



Symbols

County Facility

Percentage Positive

- 0% to 5%
- 6% to 10%
- 11% to 15%
- 16% to 19%
- 20% to 100%

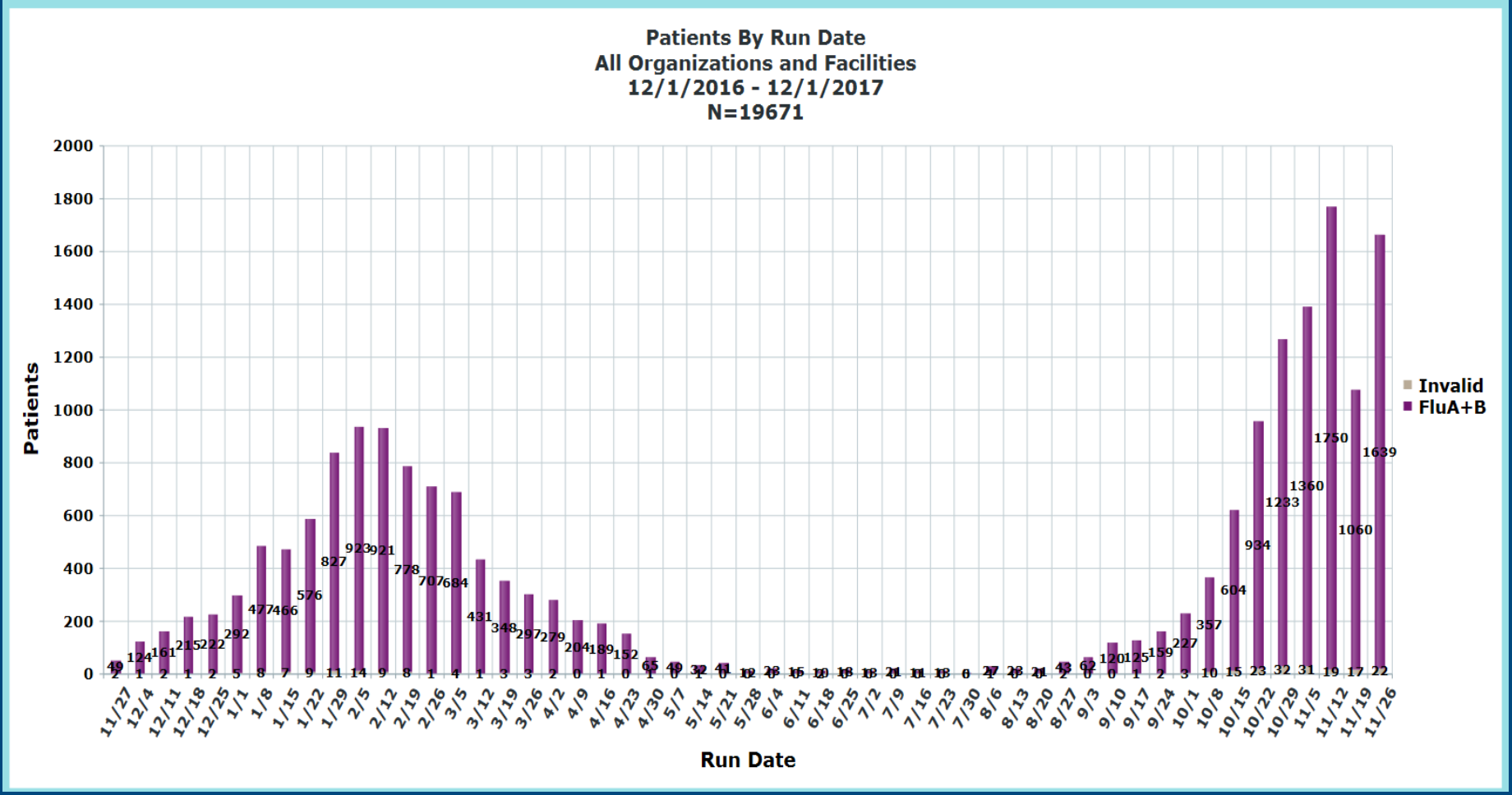
Number of Tests

- 1 to 50
- 51 to 250
- 251 to 500
- 501 to 750
- More than 750

11/1/17 to 12-1-17

DALLAS County: Influenza Status Patients By Run Date

12-1-16 to 12-1-17

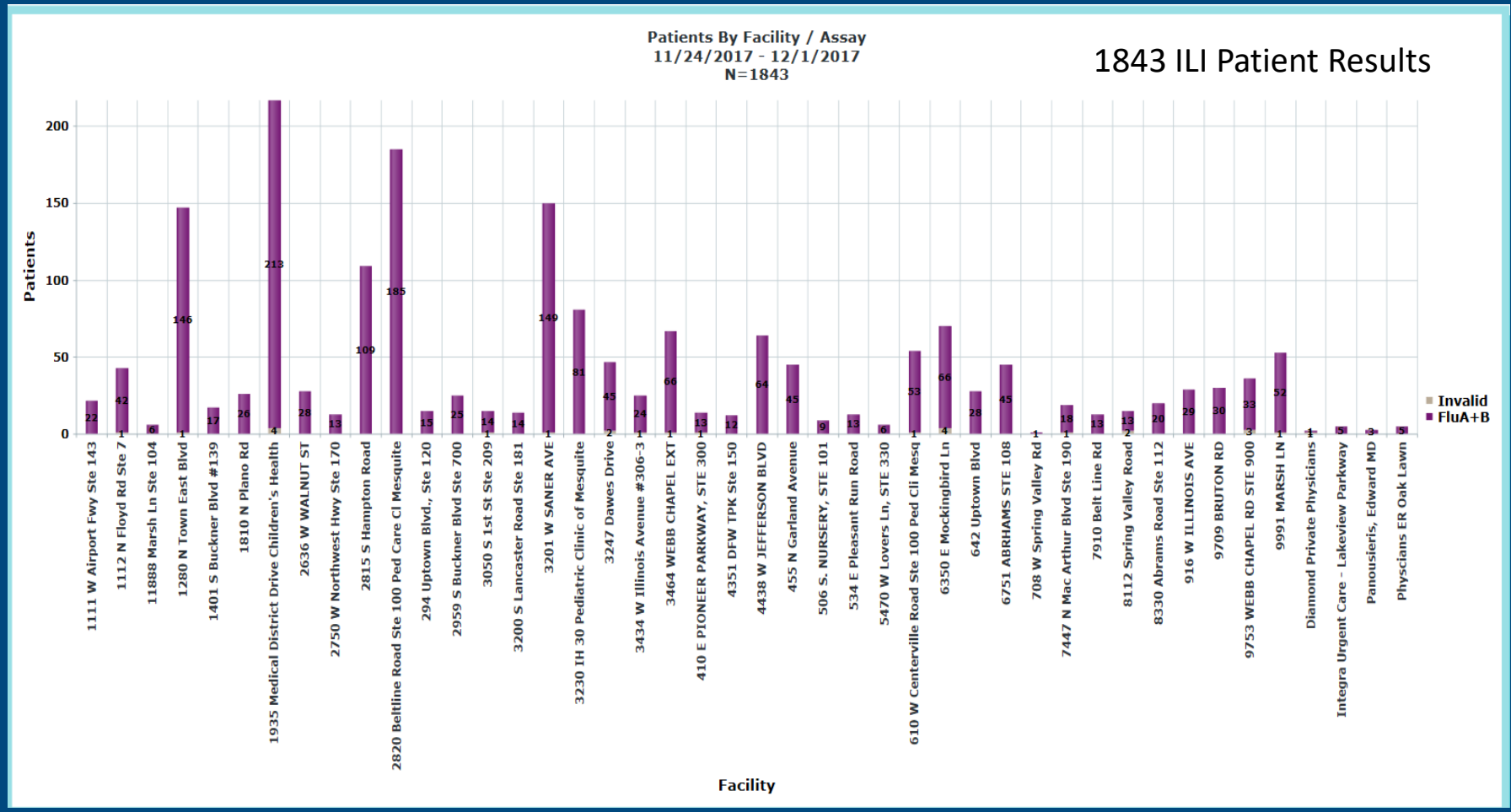


You can look at trends in your country, states, and even facilities over durations of interest and selected by you.

DALLAS COUNTY: Influenza Results by Facility

ONE WEEK's RESULTS

Nov. 24, 2017 to Dec. 1, 2017



There were 50 different sites transmitting results in Dallas County. User's can get real-time updates for one or more facilities for which they are responsible.

User can review performance daily for all sites for which he/she is responsible.

Using wirelessly transmitted data for mobile app

Mobile App for Telephone

Public Service App

- **Uses wirelessly-transmitted data on a daily basis**
- **Presents a near real-time influenza status (Map) for community, state, or nation by zipcode or county name**
- **Educates the public**
  - What is influenza?
  - What are its symptoms?
  - How is it spread?
  - Who is at greatest risk?
  - Where can you get vaccinated
  - Where can you be tested?
  - Are there treatments?
  - How can influenza be prevented?

About The Flu

A single sneeze or cough can...

contain up to

200,000,000

virus particles

travel at

50 mph

and up to 6 feet

and they can survive for

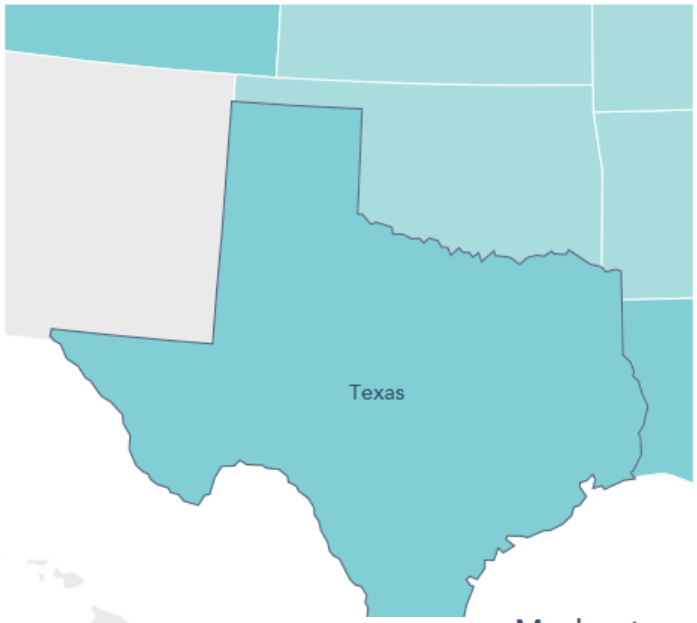
hours

in the air and on surfaces.

All it takes is exposure to a few tiny virus particles to get the flu (influenza).

And if it's easy to **get** the flu, that means it's really easy to **give** the flu to others.

Moderate



Moderate

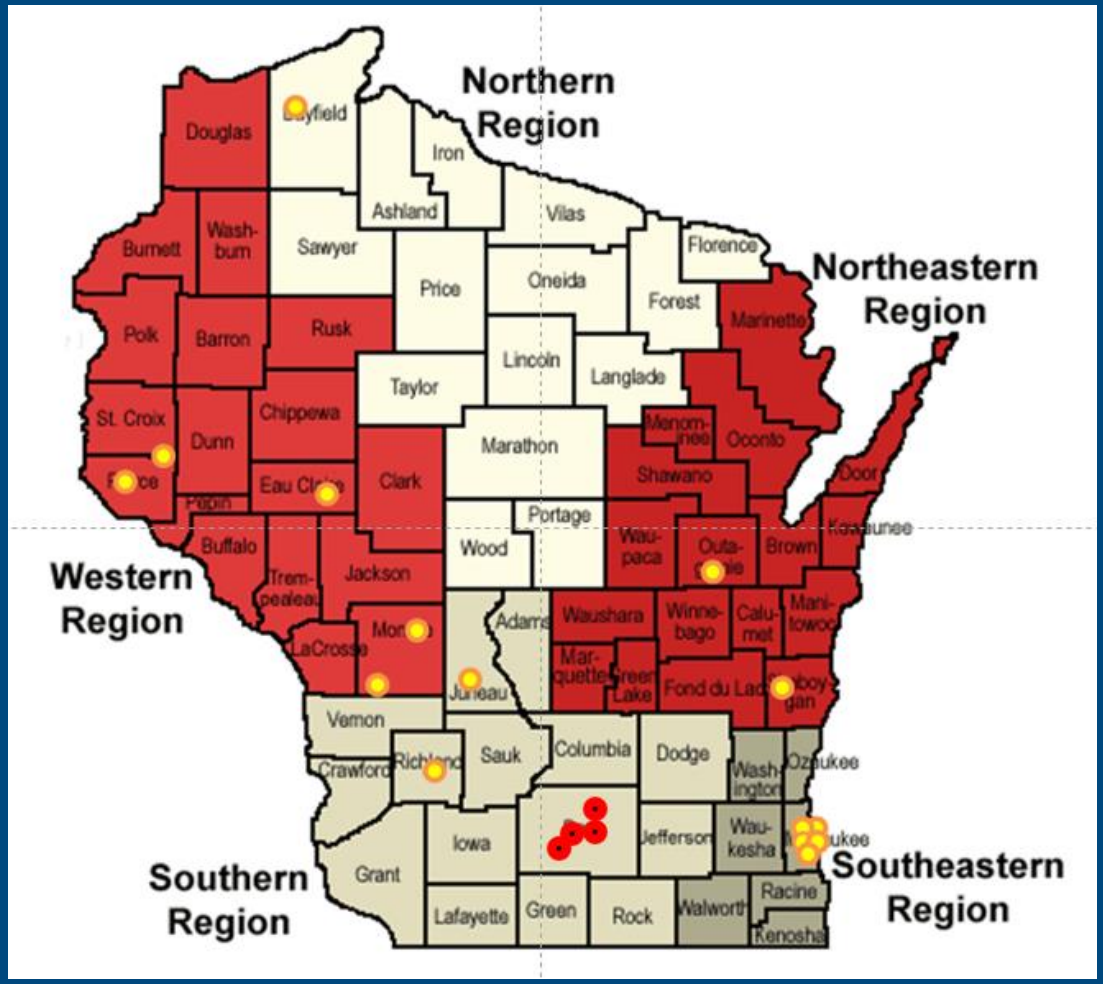
Who's getting the flu in Dallas County, TX?

See the positive flu cases in Dallas County, TX by age group:

The Littlest Ones	AGE 0-6	53%
Children	AGE 7-17	38%
Young Adults	AGE 18-24	1%
Adults	AGE 25-64	6%
Seniors	AGE 65+	2%

Comparison of RADT's wireless surveillance to Wisconsin's Surveillance

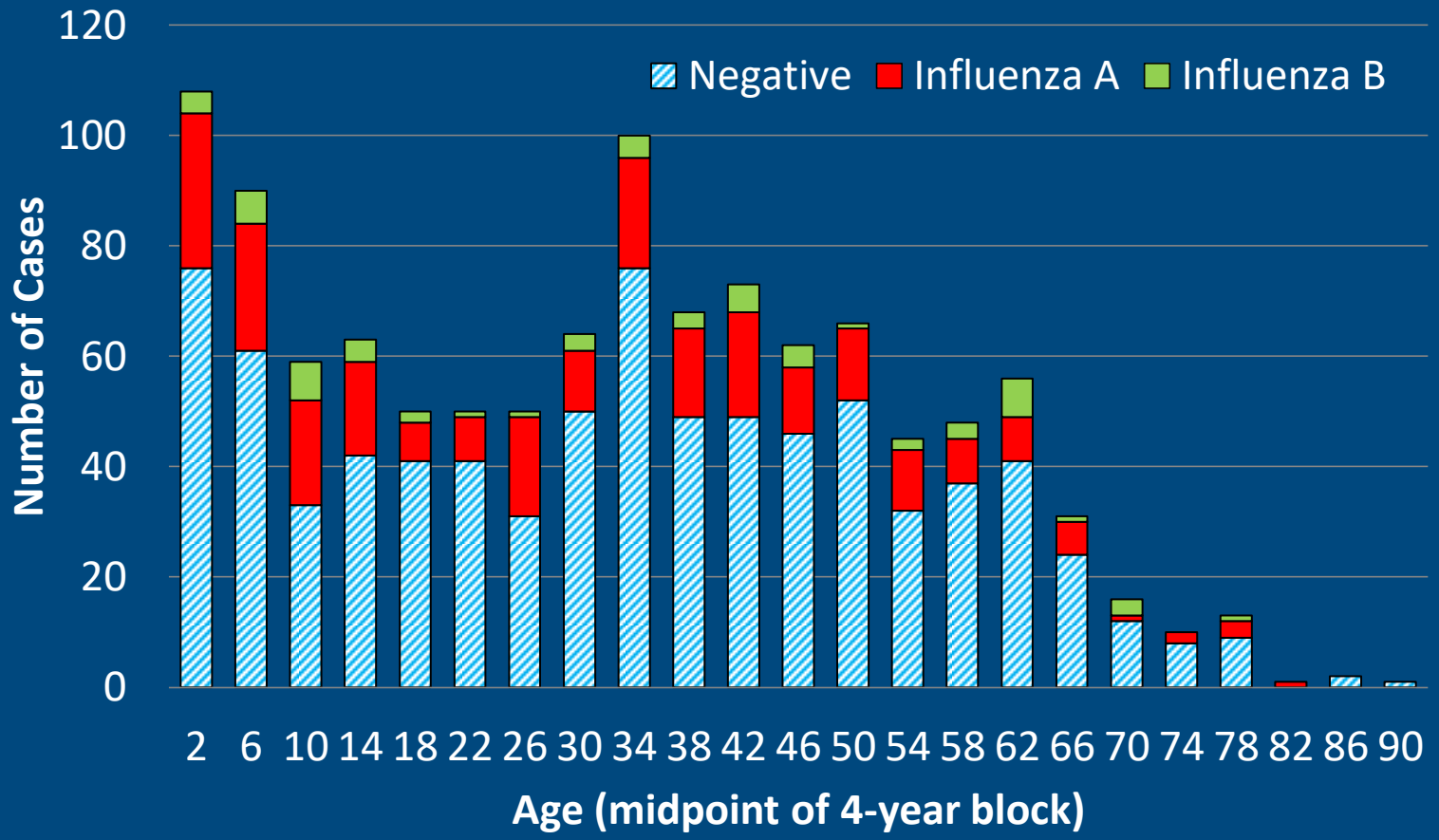
EXAMPLE: Locations of Real-Time Influenza Surveillance Network



J. Temte et al. "New method for real time influenza surveillance in primary care". JABFM (2017) 30 (5): 615-623

Surveillance Population

(N=1,133 ARI and/or ILI patients)



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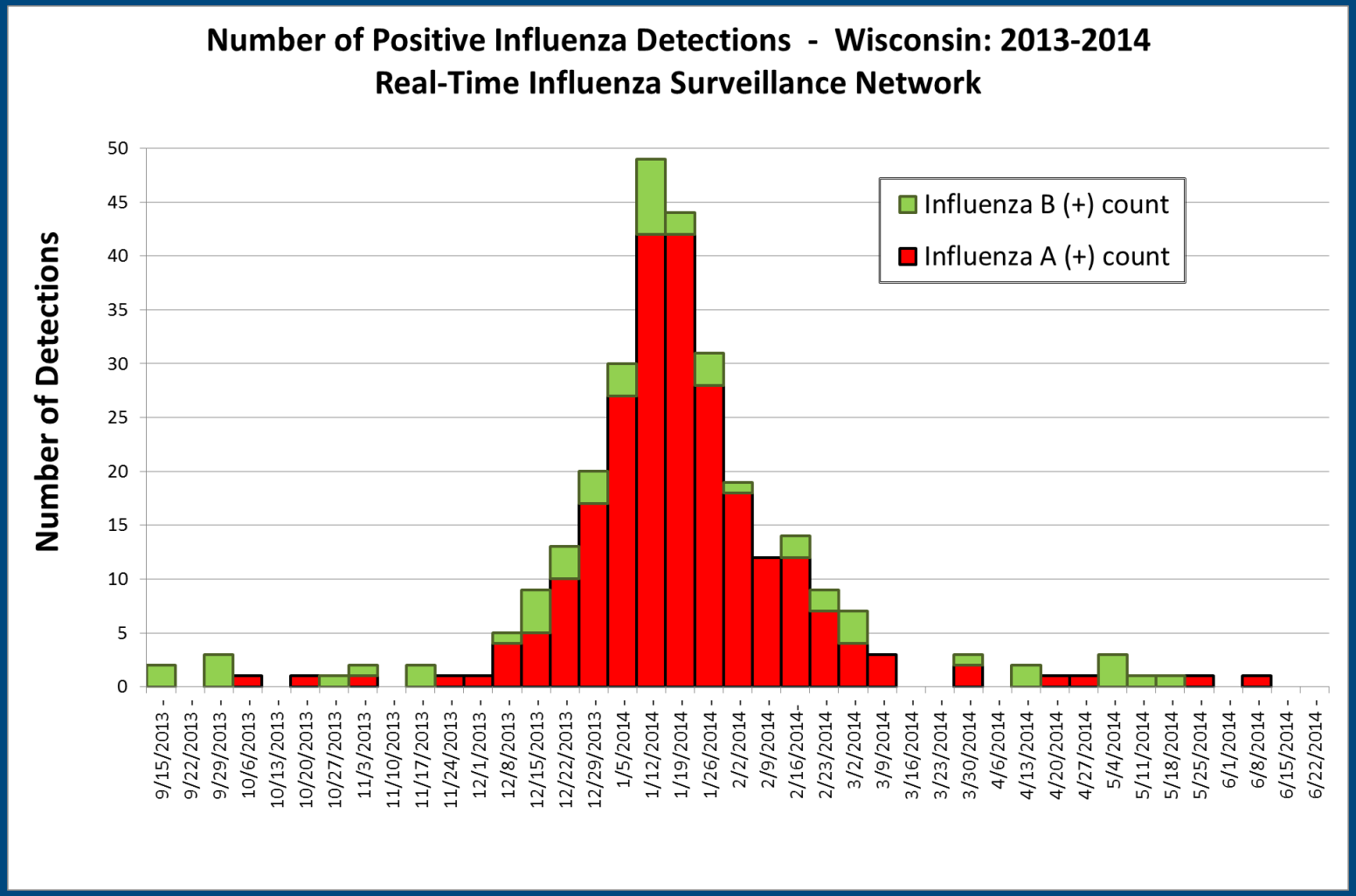
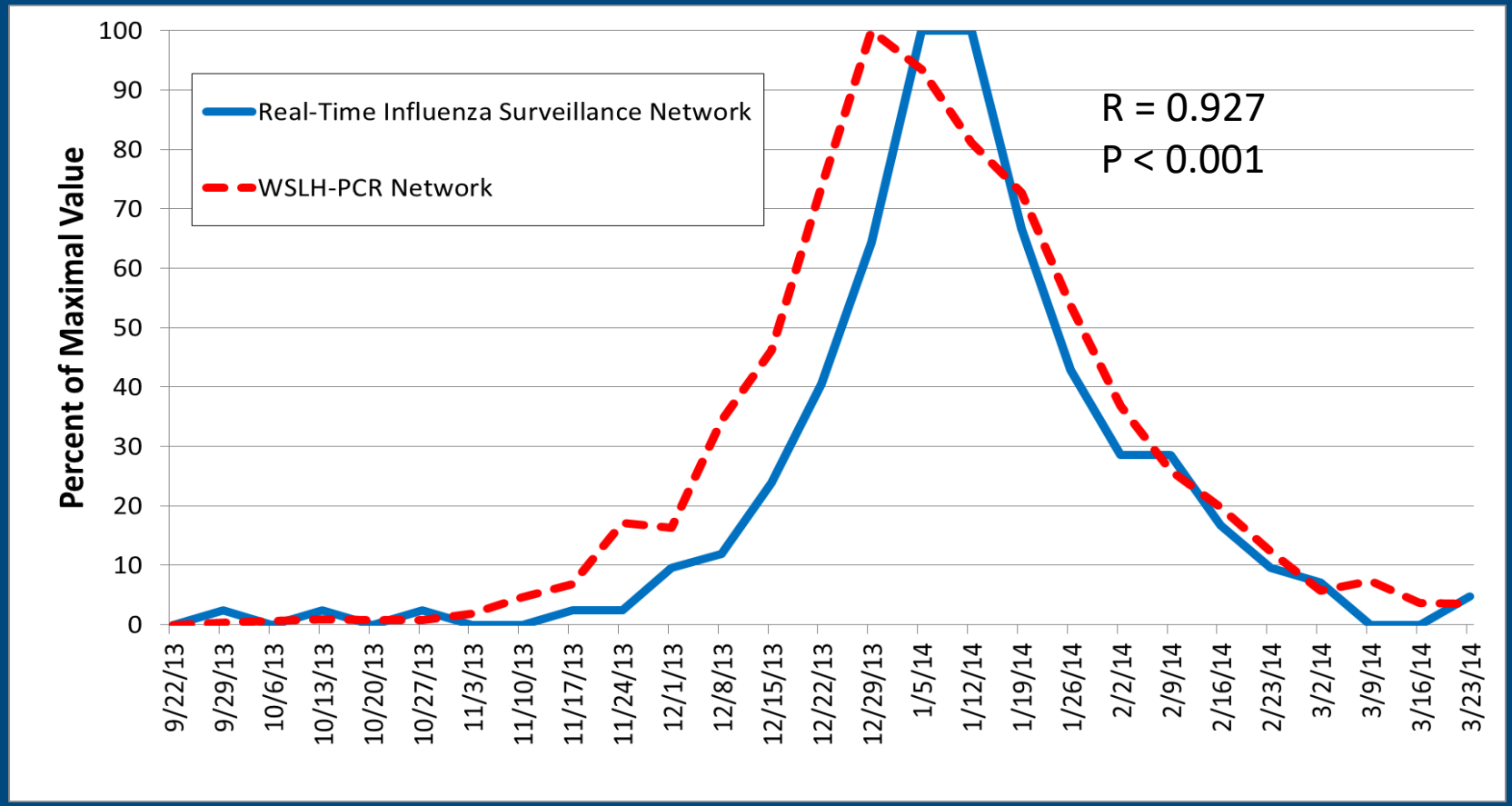
Epidemic Curve



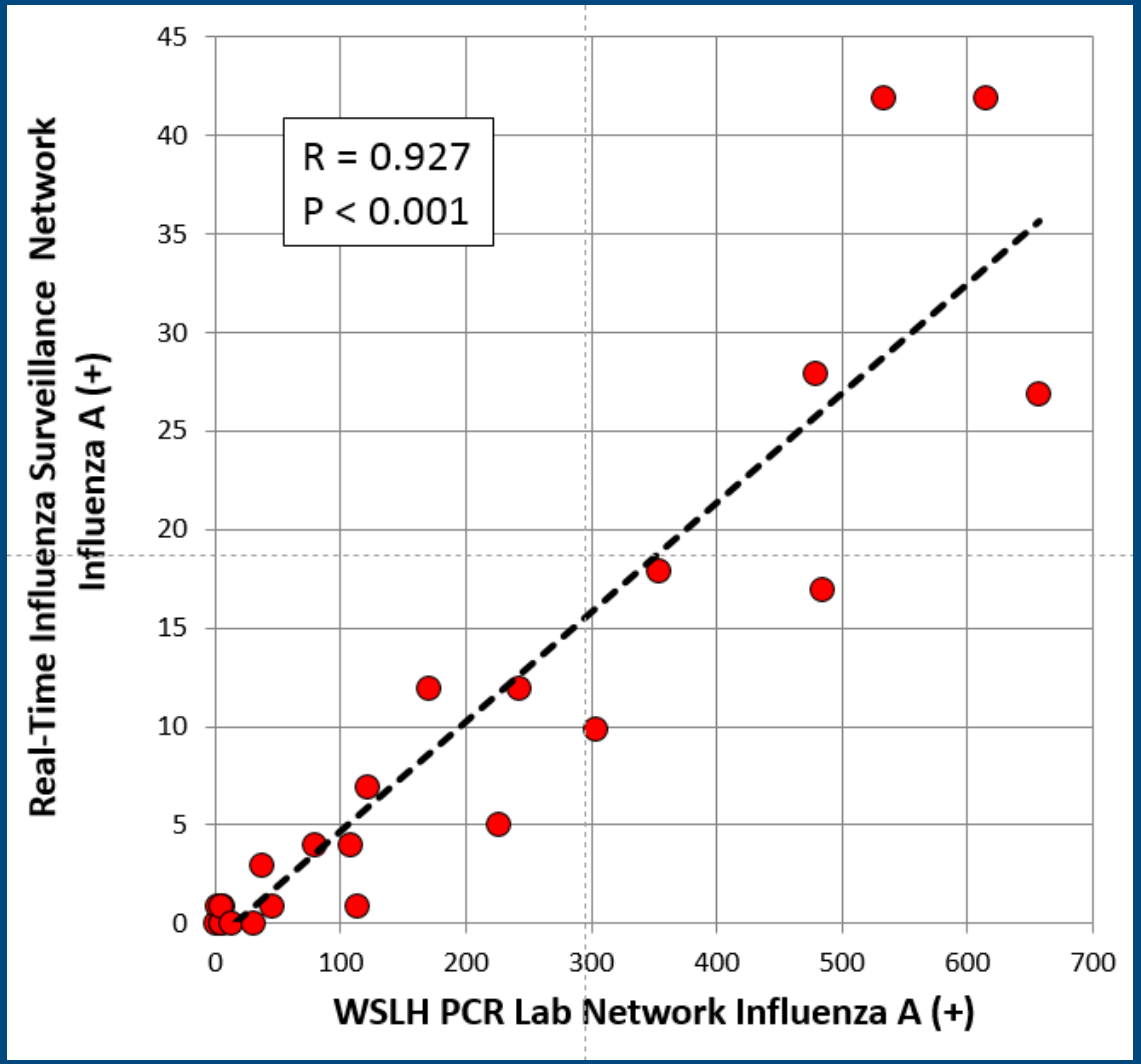
Comparison between Real-Time and WSLH PCR laboratory Network



RT-PCR data were delayed 1 to 2 weeks compared to near real-time result with this CLIA-waived RADT.

N = 1,119 ILI or ARI patients.

Comparison between Real-Time and WSLH PCR laboratory Network



RADT Use for Surveillance

Why RADTs?

1. In respiratory season, moving patients through the clinic quickly is important. Time for busy physicians, nurses and assistants comes at a premium.

2. Some RADTs give results within 3 minutes

3. The sooner antiviral therapy, e.g. oseltamivir or zanamivir, can be administered the better. Most effective within 48 hours of onset of illness.

4. Early treatment reduces virus production, secreted levels of virus, and risk of spreading disease in a community.

5. Early treatment diminishes symptomatic period by 1 to 2 days, reduces numbers of admissions, and reduces morbidity and mortality, especially in elderly and high risk groups.

Why RADTs (Cont'd.)

6. For hospitalized patients, increases antiviral use by 3x to 9X
7. For hospitalized patients, decreases antibiotic use by over 50% (antibiotic stewardship)
8. Invariably accompanied by reduction in other laboratory tests
9. Decreases length of stay in hospital
10. For hospitalized patients, early antiviral treatment reduces mortality
11. Recent guidelines recommend nonpharmacologic management and neuraminidase inhibitors (most effective within 48 hours)
12. Performance versus PCR can be excellent, depending on assay, time after onset of disease, proper sample collection

Blaschke, A. et alia. J. Pediatr Infect. Dis.Soc. 2013;doi:10.1093/jpids/pit071

Semret, M. et alia. J. Infect. Dis. 2017 vol. 216: 937-944

Appiah, G., et alia. Clinical Infectious Diseases, Volume 64, Issue 3, 364-367. 2017

Bonner, A., et alia. Pediatrics. 112: 363-367. 2003

J. Temte et alia. JABFM (2017) 30 (5): 615-623

Schweiger B. & Lehmann H., Robert Koch-Institut, National Reference Centre for Influenza, Berlin, Germany.

RADTs' Performance for Influenza Surveillance

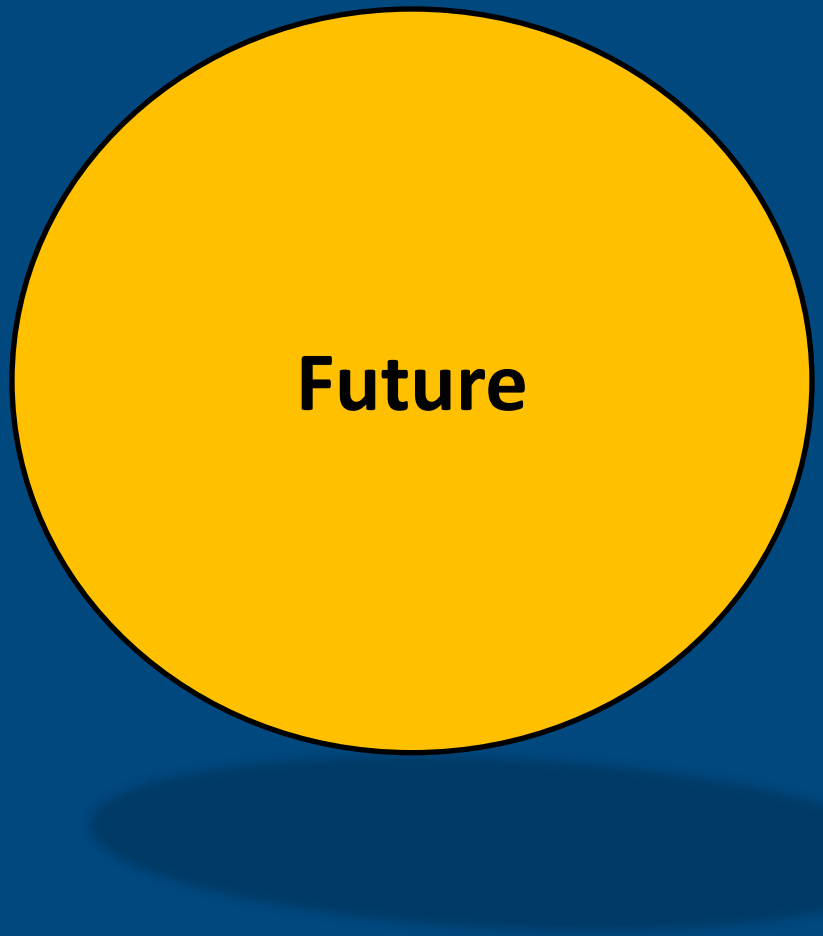
- **Limitations.**
  - Clinical sensitivity and specificity. Must meet new FDA reclassification performance requirements.
  - Geographic coverage
  - Use in different settings sometimes limited
- **Advantages**
  - Turn around Time
  - Ease of Use
  - Cost
  - Used at different types of sites
  - Automatic, objective result interpretation*
  - Wireless transmission within seconds to minutes*
  - Excellent sensitivity for samples taken within 48 hours of onset of symptoms*

Using RADTs with wireless connectivity, By Accessing Internet with Password, you can:

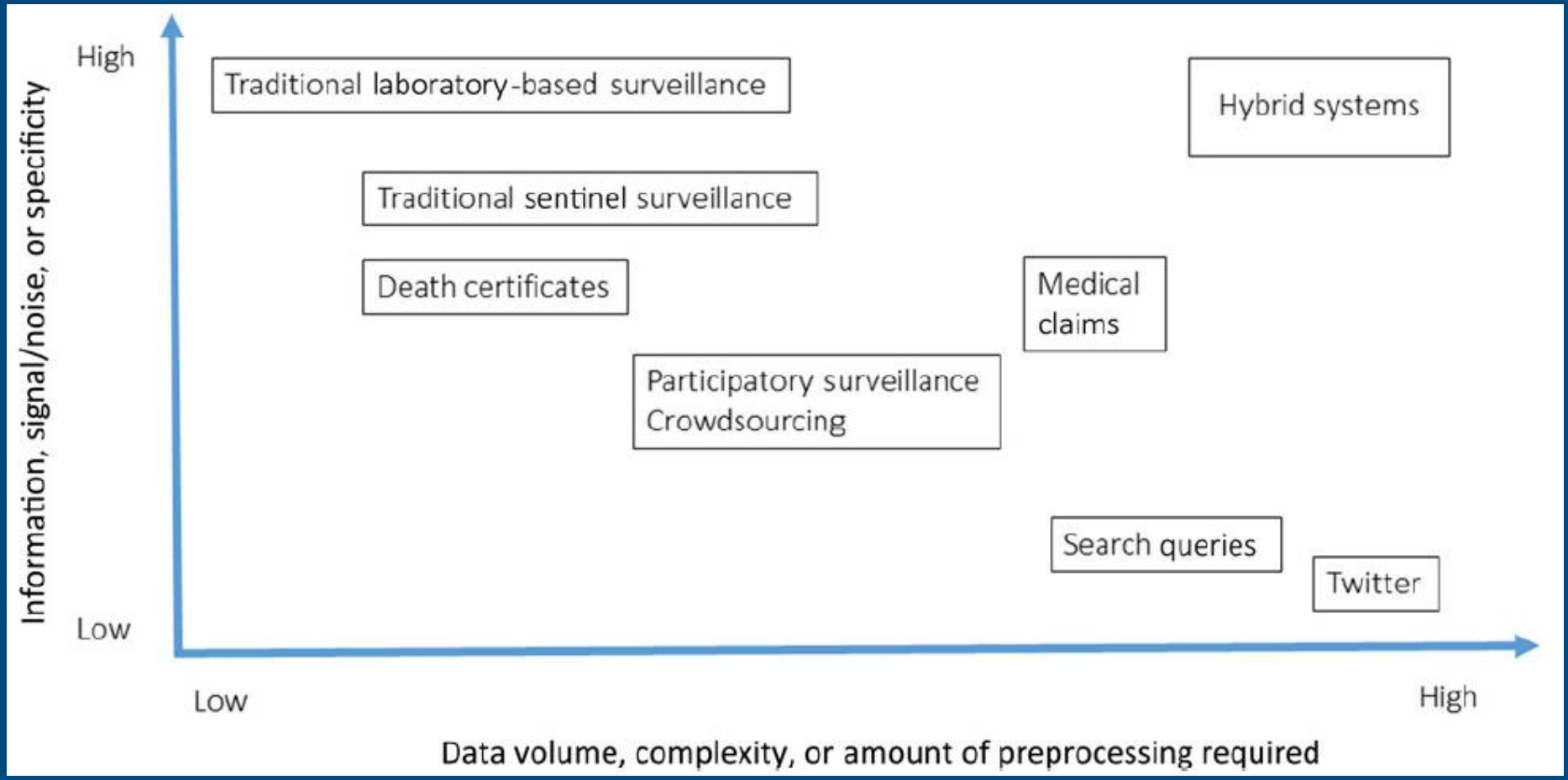
- Track arrival of influenza in your State, County, and community by Sofia and, now, by Solana.
- Anticipate staffing and inventory needs.
- Monitor test results in your organization and across your facility networks.
- Monitor and document QC results by operator and facility.
- Support operator/technical staff training initiatives.
- Provide Laboratory Director ready access to instrument and kit useage, testing frequency, resource needs—across your entire network of facilities.
- Facilitate forecasting (historical comparisons)
- Generate reports, charts, and graphs---all at one's finger tips.

RADT, like the one I described, is of Value to Hospital and Healthcare Staffs

- Places medical director, ER physicians, pharmacy and hospital staff on early notice that influenza (or RSV or Strep A) is arriving in their community.
- Enables official notices to nurses, physician assistants and physicians that influenza is in the community
- Enables resource planning, e.g. antiviral needs
- Forecasts emergency room burden and resource needs
- Anticipates potential surge in hospital admissions
- Facilitates proper diagnosis of patients with ILI


Future

Characteristics of Infectious Disease Surveillance Systems



"Hybrid systems combining traditional surveillance with big data streams fall in the desirable zone associated with high information return and high data volume".

From: Simonsen, L. et alia. "Infectious Disease Surveillance in the Big Data Era: Towards Faster and Locally Relevant Systems. J. Infectious Dis. 214 (Suppl 4), S380-S385. (2016)

Conclusion

Conclusion

- There is a long history of development and maturation of infectious disease surveillance in the United States, starting with President John Adams in 1798
- After 125 and 150 years, respectively, came creation of the FDA and CDC, respectively, in the 20th century.
- The CDC has led the way to develop reliable and useful surveillance to help ensure the public health and safety
- They have struggled with difficult-to-overcome impediments.
- The advances in diagnostic technology and digital communications bring new, exciting opportunities to the 21st century.

Conclusion (Cont'd.)

- Because they are new, they carry their own advantages and uncertainties, and these are only now being recognized, analyzed and addressed.
- The application of RADT assay(s) with wireless technology is one of the new capabilities that shows promise for surveillance and monitoring disease. Some molecular methods, not discussed, are already available as well.
- The future of surveillance will likely use some combination of all that has preceded, giving us a hybrid system that employs data from a wide breadth of sources.
- It is an exciting time, but needs a great deal of work and investment to validate the potential of the new methods---as well as of the anticipated hybrids of the new with the old.
- Government investment will be critical to achieving their potential.


Thank you!