Global Hepatitis Outbreak & Surveillance Technology

Yury Khudyakov, PhD
Division of Viral Hepatitis
CDC
Atlanta, GA
Introduction
Provides accurate information for designing, guiding and monitoring public health interventions

**SEARCH**
Identify communities at risk

**TEST**
Generate Information

**CONTAIN**
Recommend Intervention

**CONTROL**
“Spinoza” Track Performance

**Surveillance**

**Intervention**

**Management**
Geospatial Mapping of High-Risk Communities
Drug dealer

The volume of searches shows a daily pattern, peaking around 2am

Heroin

The volume of searches shows a daily pattern, peaking around 3am

Overdose

The volume of searches shows a daily pattern, peaking around 4am
The following search terms have the highest correlation with real overdose rates (2015)

- the web-search term that is the most correlated with real overdose rates is “overdose”
- Many other have an obvious association with drugs.

https://www.cdc.gov/drugoverdose/data/statedeaths.html
Correlation of web-terms with overdose rate

Top 10 of target year that are also in top 10 of previous year

Number of variables

Correlation

Between rate of target year and best web-term of the same year

Between web-terms of target year and web-terms of previous year
Dynamic Overdose Vulnerability Estimator (DOVE)

Early Detection of Vulnerable Communities

Scott County, IN
HIV/HCV outbreak among PWID associated with opana, 2015

- “Opana” correlates with overdose rates by DOVE (R = 0.95)
- Peak of opana searches - February 2012

2016 US Overdose Rates

Reported Dec 2017

Estimated Jan 1st 2017

DOVE accuracy – 93%

County-level estimates
KY: 120 counties
Network-Guided Molecular Surveillance
Global Hepatitis Outbreak & Surveillance Technology (GHOST)

Until Recently

Sequences → Computer model

GHOST Detection

Sequences → Computer model (Cyber-Assay) → Transmission Links

\[ a_i = \sum_{j=1}^{n_i} q_{ij} + d_i a_i - a_i \sum_{j=1}^{n_i} (q_{ij} - d_j) a_j \]

HAV, HBV, HCV
HIV OUTBREAK
Scott County, IN
2015

Reported number of acute hepatitis C cases
United States, 2000–2016

CDC, National Notifiable Diseases Surveillance System (NNDSS)

Rising HCV incidence

HIV and HCV molecular testing

Injection of prescription opioid

Public health emergency declared

Federal support requested

Over 35,000 cumulative syringes dispensed

Over 77,000 cumulative syringes dispensed

88% in care
60% on ART
44% virally suppressed

Syringe exchange started

Local HIV clinic opened

HIV testing staff & DIS deployed

Cluster identified

Initial diagnosis

HIV outbreak

Incident command established

Timeline of Interventions

CDC, National Notifiable Diseases Surveillance System (NNDSS)
Phylogenetic Analysis

GHOST Network

<table>
<thead>
<tr>
<th>Groups</th>
<th>Clusters</th>
<th>Cases</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clusters</td>
<td>23</td>
<td>198</td>
<td>70.46</td>
</tr>
<tr>
<td>Unrelated</td>
<td>0</td>
<td>83</td>
<td>29.54</td>
</tr>
<tr>
<td>Total</td>
<td>23</td>
<td>281</td>
<td>100</td>
</tr>
</tbody>
</table>

Node = 1 patient

Links = Sharing of variants among patients (>96.3% identity)

Groups n

Major HCV cluster 130
HIV coinfections 43
Mixed HCV infections 50
Guided Molecular Surveillance

Random Sampling

Example

Improving sampling

Limited sampling

Improved sampling

Guided Sampling

PWID Network of Transmission

Improving case identification

High-Risk Community 1

General Population

Unrecognized Outbreaks

High-Risk Community 2

Targeted Sampling

Example
Network-Guided Public Health Interventions
Network structure affects spread of infections and public health information

- **Infection** among members of a high-risk contact network
- Rate of spread through network is affected by:
  - Network structure
  - Position of the node introducing infection to the network

- **Peer education** as “infection” of network with public health messages
- The rate of education dissemination and adoption is affected by position of a peer-educator in network

![Diagram](image_url)
**Targeted Network-based Interventions (TNI)**

**Intelligent Network DisRuption Analysis (INDRA)**

guiding and monitoring efficacy of public health interventions

- Detects *transmission networks* in a near-real time
- Guides most *efficient and cost-effective intervention*
- Provides *new instant measures* for monitoring efficiency of public health intervention
- *Personal/Community benefits*: rapid reduction of probability to be infected with HCV

---

**Network Efficiency Reduction**

Linkage to Harm Reduction/Care services of ~16% HCV-infected PWID identified by TNI ~65% HCV-infected PWID identified randomly would result in 20x reduction of HIV spread in the Indiana PWID network

**Incidence Reduction**

Greater knowledge of transmission network results in a greater reduction of incidence

TNI is up to 12x more efficient in reduction of incidence than random strategy

**Targeted Peer-Education Intervention (PEI)** results in ~3-fold increase of effects of TNI vs Random interventions
Decline in Network Efficiency at Different Levels of Transmission Reduction and Affected Population Size

Overall, network-based intervention is 1.3 times more efficient than random intervention.
SUMMARY

• **Geospatial mapping**
  • To estimate numbers and rates of drug overdose death in a *near-real* time
    • “Smoke Alarm”
  • To help identify communities most vulnerable to acquisition of HBV, HCV and HIV

• **Network-Guided Molecular Surveillance**
  • To identify HCV infected persons from potentially high-risk populations
    • Contact tracing of the GHOST-identified high-risk persons helps to improve
      • Sampling efficiency
      • Identification of transmission networks
      • Identification of high-risk communities
      • Identification of HCV infected cases

• **Network-Guided Interventions**
  • Network structure affects individual contributions to infection dissemination
  • INDRA helps to develop network-guided public health interventions
    • Cost-effective as compared to random interventions
    • Ranks contribution of individuals to transmission
    • Network-guided interventions outperform random strategies
      • As measured by reduction in network efficiency and incidence rate
Global Hepatitis Outbreak & Surveillance Technology

Contact: ghost@cdc.gov

GHOST:
BMC Genomics 2017, 18(Suppl 10): 916
BMC Bioinformatics 2118, 19(Suppl 11): 358

GHOST Networks:
EBioMedicine 2018, 37: 374-381
PloS One 2019, 14(3): e0212350

INDRA:
Infect Genet Evol 2018, 63: 204-215