Vaccinating Against HPV:
An attempt to further the Prevention of Cervical Cancer

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Objective

- Explore various vaccination patterns to minimize the number of cervical cancer cases resulting from Human Papillomavirus (HPV).

Strategy:
1. Create a network of individuals.
2. Spread the virus throughout the network.
3. Implement vaccination patterns.
What is a Sexually Transmitted Infection?

An STI is “any infection that can be transmitted through any type of sexual contact.”

- More than 20 STIs have been identified by the Centers for Disease Control and Prevention (CDC).
- STIs result in approximately 30,000 deaths annually.
- 20 million people develop health complications as a result of sexual activity.
- The most common STI is the Human Papillomavirus.
Human Papillomavirus (HPV)

HPV infects the skin and mucous membranes of the human body. It can be contracted through any genital or sexual contact.

- **Strains:**
  - 40 strains are STIs (over 130 exist).
  - Low risk strains can cause genital warts.
  - High risk strains can cause cervical cancer.

- **Detection:**
  - Pap smear for women; cannot tell which strain
  - No FDA approved method for diagnosis in men
History of HPV

- **Before 1970**
  - There is only one known strain of HPV.

- **1976**
  - HPV DNA discovered in cervical cancer.

- **1982**
  - HPV 16 and HPV 18 are discovered.

- **1990**
  - HPV and cervical cancer link is discovered.

- **2001**
  - MERCK begins clinical trials of HPV vaccine.

- **2006**
HPV Vaccine: Gardasil

- Approved for females 9-26 years old.
- 3 series vaccination:

  ▪ Protects against:
    ▪ HPV 6, 11 (genital warts)
    ▪ HPV 16, 18 (cause 70% of cervical cancer cases)
Network Construction

- **Dating Network**
  - Static and based on a scale-free network
  - Nodes: individuals
  - Edges: dating connection

- **Characteristics**
  - **Gender**
    - male, female
  - **Sexual Orientation**
    - heterosexual, homosexual, bisexual
  - **Age**
    - 9-17, 18-26, 27-39, 40-64, 65+
  - **State**
    - Susceptible, Infective, Recovered, Cervical Cancer
Node Status

Susceptible  Infective  Recovered  Cancerous

* path continues on central path

HPV 16  HPV 18
Infection

- 10% initially infected with HPV 16 and/or HPV 18
- Spreading the infection:
  - Each node dates all of its contacts.
  - The probability of sexual contact occurring depends on the node degree, $k$:
    - More contacts results in lower probability.
    - Less contacts results in higher probability.

\[ P(\text{sexual contact}) = \frac{1}{k} \]
where $k = \text{degree of the node}$
Vaccination

- 12.6% initial protection (safe practices)
- 3 doses provide virtually 100% protection
- Protection Level:

\[ P_n = P_{n-1} + w(1 - P_{n-1}), \]

where:
- \( P \) is % protection,
- \( w \) is % increase in protection per dose
- \( n \) is the number of doses.
- \( P_0 = .126 \)
- \( w = .7 \)
Vaccination Strategies

Strategy 1
- 10% of the population @ 1 dose each

Strategy 2
- 3.3% of the population @ 1 dose each
- 3.3% of the population @ 2 doses each

Strategy 3
- 3.3% of the population @ 3 doses each

Strategy 4
- 90% of females 9-26 years old @ 1 dose each

Strategy 5
- 30% of females 9-26 years old @ 1 dose each
- 30% of females 9-26 years old at 2 doses each

Strategy 6
- 30% of females 9-26 years old @ 3 doses each
Results

Network picture according to node status (S, I, R, C)

- Susceptible
- Infective
- Recovered
- Cancerous

$t=60$, with vaccination
Results

SIRC: No Vaccination vs. Strategy 1

<table>
<thead>
<tr>
<th># of People</th>
<th>Susceptible 0</th>
<th>Infective 0</th>
<th>Recovered 0</th>
<th>Cancerous 0</th>
<th>Susceptible 1</th>
<th>Infective 1</th>
<th>Recovered 1</th>
<th>Cancerous 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time (months)</td>
<td>0</td>
<td>10</td>
<td>20</td>
<td>30</td>
<td>40</td>
<td>50</td>
<td>60</td>
<td></td>
</tr>
</tbody>
</table>

- Susceptible 0: Decrease to 0 after 10 months
- Infective 0: Reach peak at 20 months, then decrease
- Recovered 0: Increase from 0 to 1000 by 60 months
- Cancerous 0: Low and steady throughout

- Susceptible 1: Increase from 0 to 1000 by 60 months
- Infective 1: Reach peak at 20 months, then decrease
- Recovered 1: Increase from 0 to 1000 by 60 months
- Cancerous 1: Low and steady throughout
Analysis & Conclusion

1 Std. Dev. +/- Sample Mean

- Strategy 1: lowest mean
- Strategy 2: least variance
Future Research

- Implement genetic algorithm
- Create changing network edges
- Implement node age progression
- Implement booster shots if needed
- Vaccinate men and women outside 9-26 year age bracket if possible
- Some female nodes overcome cervical cancer
- Implement risk perception
Discussion
Acknowledgements

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References

- MERCK & CO., Inc. (gardasil.com)
- Centers for Disease Control and Prevention
- The United States Census Bureau