Geographic Clusters in Underimmunization and Vaccine Refusal

Tracy A. Lieu, MD, MPHa, G. Thomas Ray, MBAa, Nicola P. Klein, MD, PhDab, Cindy Chung, MDb; Martin Kulldorff, PhDd

abstract

BACKGROUND AND OBJECTIVE: Parental refusal and delay of childhood vaccines has increased in recent years and is believed to cluster in some communities. Such clusters could pose public health risks and barriers to achieving immunization quality benchmarks. Our aims were to (1) describe geographic clusters of underimmunization and vaccine refusal, (2) compare clusters of underimmunization with different vaccines, and (3) evaluate whether vaccine refusal clusters may pose barriers to achieving high immunization rates.

METHODS: We analyzed electronic health records among children born between 2000 and 2011 with membership in Kaiser Permanente Northern California. The study population included 154,424 children in 13 counties with continuous membership from birth to 36 months of age. We used spatial scan statistics to identify clusters of underimmunization (having missed 1 or more vaccines by 36 months of age) and vaccine refusal (based on International Classification of Diseases, Ninth Revision, Clinical Modification codes).

RESULTS: We identified 5 statistically significant clusters of underimmunization among children who turned 36 months old during 2010–2012. The underimmunization rate within clusters ranged from 18% to 23%, and the rate outside them was 11%. Children in the most statistically significant cluster had 1.58 (P < .001) times the rate of underimmunization as others. Underimmunization with measles, mumps, rubella vaccine and varicella vaccines clustered in similar geographic areas. Vaccine refusal also clustered, with rates of 5.5% to 13.5% within clusters, compared with 2.6% outside them.

CONCLUSIONS: Underimmunization and vaccine refusal cluster geographically. Spatial scan statistics may be a useful tool to identify locations with challenges to achieving high immunization rates, which deserve focused intervention.

WHAT'S KNOWN ON THIS SUBJECT: Parent refusal and delay of childhood vaccines has increased in recent years and is believed to cluster in communities. Such clustering could pose public health risks and barriers to achieving quality benchmarks for immunization coverage.

WHAT THIS STUDY ADDS: We found that underimmunization and vaccine refusal cluster geographically. Spatial scan analysis may be a useful tool to identify locations where clinicians may face challenges to achieving benchmarks for immunization coverage and that deserve special focus for interventions.
Parental vaccine hesitancy, including refusal and delay of childhood vaccines, has drawn increasing national concern over the past decade.\(^1,2\) Underimmunization has been associated with elevated risk of vaccine-preventable disease in individual patients.\(^3\)–\(^9\) Beyond individual risk, nonmedical immunization exemptions have been associated with increased community risk of measles and pertussis outbreaks.\(^4,6,10\)

For optimal public health and patient care, clinicians and health care systems ideally should tailor care to their communities. The ability to identify clusters of underimmunization and vaccine refusal would help providers focus their efforts on the parents in communities with the greatest concerns, as well as identify areas at elevated risk for outbreaks of vaccine-preventable diseases. Identification of disease clusters has been used in many public health problems. However, in evaluating underimmunization, geographic clustering has been applied in only a few studies focused on nonmedical exemptions.\(^6,10\)

We designed this study to evaluate the feasibility of identifying geographic clusters of events that represented vaccine hesitancy using the population-based data of a large regional integrated health care system. Our aims were to (1) describe the geographic clustering of underimmunization and vaccine refusal, (2) compare how these events cluster among different vaccines, and (3) evaluate whether vaccine refusal clusters may pose barriers to some clinician groups achieving the high coverage rates specified in quality benchmarks.

**METHODS**

**Study Population and Data Collection**

Kaiser Permanente of Northern California (KPNC) is a nonprofit, integrated health care delivery system providing care to >3 million members, including ~30,000 annual births. KPNC provides services at 21 hospital-based medical centers, and >200 medical office buildings,\(^11\) spanning 200 miles from Santa Rosa to Fresno and 100 miles from Sacramento to San Jose. In many communities, KPNC is the dominant provider, with ≥40% market share. KPNC patient demographics reflect the general population in the Northern California region, although persons with low education and income are underrepresented.\(^12\)

Immunizations and other clinical information are kept in a fully electronic medical record system. All routine pediatric immunizations are administered to KPNC members at no charge.

In this retrospective cohort analysis, we identified all infants born between January 1, 2000, and December 31, 2009, who had continuous KPNC membership from birth until age 36 months. To focus on children using KPNC for primary care, we excluded those without ≥2 primary care visits by their first birthday. Race/ethnicity was identified via a search of electronic medical records and administrative databases. Using KPNC membership databases, we identified the home address of each child at the time of his or her 36-month birthday. Children were assigned to a census block group from the United States 2010 decennial census based on their home address. Census block group statistics were based on the 2006–2010 American Community Survey data collected by the US Census Bureau.\(^13,14\)

**Definitions of Outcomes and Predictors**

Children were defined as “underimmunized” if, by 36 months of age, they missed ≥1 of the vaccines recommended by the Centers for Disease Control’s Advisory Committee on Immunization Practices.\(^15\)–\(^17\) For years 2000 to 2003, children were expected to have received 3 doses of hepatitis B by their 36 month birthday; 4 doses of diphtheria and tetanus toxoids and acellular pertussis vaccine; 2, 3, or 4 doses (depending on vaccine manufacturer and due date of the booster dose) of Haemophilus influenza type b vaccine (Hib); 3 doses of inactivated polio virus vaccine; 1 dose of measles, mumps, rubella vaccine (MMR); and 1 dose of varicella zoster virus vaccine (VZV). In addition to these, children were expected to receive 4 doses of pneumococcal conjugate vaccine (PCV) beginning in 2004, 1 dose of hepatitis A (HepA) beginning in 2009, and 2 or 3 doses (depending on vaccine manufacturer) of rotavirus vaccine beginning in 2010. Because of vaccine shortages, we did not require children to receive the Hib booster dose if the timing of that dose fell between December 1, 2007, and December 31, 2009.\(^18,19\)

To account for the introduction of new vaccines, in our analysis, we did not count a newly introduced vaccine as required until 3 calendar years after it was added to the Advisory Committee on Immunization Practices schedule. Thus, although PCV was added in 2001, we only included it as required for children whose first PCV shot was due after December 31, 2003. Similarly, we only treated HepA vaccine as required for children whose first HepA dose was due after December 31, 2008, and rotavirus for children whose first rotavirus dose was due after December 31, 2009.

As a secondary measure of underimmunization, we used the “combination 3” performance measure used by the Healthcare Effectiveness Data and Information Set (HEDIS). This HEDIS measure included all children who were enrolled in the health plan on their second birthday and who were enrolled for at least 11 of the 12 months before this. Children were considered underimmunized if they...
did not receive the following immunizations by their second birthday: 4 diphtheria and tetanus toxoids and acellular pertussis vaccine, 3 inactivated polio virus vaccine, 1 MMR, 2 Hib (3 if year 2011 and 2012), 3 hepatitis B, 1 VZV, and 4 PCV. Some families limit the number of injections at each visit but still have their children receive all required immunizations by 36 months of age. To evaluate this phenomenon, we adopted a definition used in a previous study and classified families as “shot limiting” if a child did not receive >2 injections on any day before their 36-month birthday.20 “Vaccine refusal” was defined as receiving ≥1 diagnoses (International Classification of Diseases, Ninth Revision, Clinical Modification [ICD-9-CM]) denoting vaccine refusal at any time before their 36-month birthday. Vaccine refusal ICD-9-CM codes used at KPNC during this time were V6405, V6406, and V6407. Because the use of these codes was rare before 2007, analyses of vaccine refusal were restricted to children born between January 1, 2007, and December 31, 2009.

Statistical Analyses

To determine if there was a trend over time in the proportion of children who were underimmunized, we created an analytic data set with a record for each calendar year from 2003 to 2012 with a variable indicating the number of children turning 36 months of age that year who were underimmunized, a variable indicating the total number of children turning 36 months of age that year, and a numeric variable indicating the year. A Poisson regression was run in which the dependent variable was the log of the number of underimmunized children in the calendar year, and the offset variable was the log of the number of children turning 36 months of age that year, and a numeric variable indicating the year. A Poisson regression ignoring PCV, HepA, and rotavirus, which were introduced during the study period.

To assess individual-level demographic and neighborhood-level predictors of underimmunization, we performed logistic regression in which the dependent variable was whether the child was underimmunized, the individual-level independent variables were calendar year, gender, and race/ethnicity, and the neighborhood-level variables (proportions of the block group population) were race/ethnicity, Spanish speakers, households with income below the poverty level, housing units occupied by owners, and education (less than high school, and graduate or professional degree).

Geographic clusters of underimmunization, shot-limiting, and vaccine refusal were identified by using the spatial scan statistic and the free SaTScan software.21 The Bernoulli version of the spatial scan statistic was used to detect and evaluate geographic clusters with a high proportion of cases (eg, underimmunized children) versus controls (eg, fully immunized children) at a statistical significance level of $P < .05$. This is done by gradually scanning a circular variable size window across space, noting the number of cases and controls inside each of many thousands of evaluated circles, and calculating the likelihood for each. The circle with the maximum likelihood is the most likely cluster; that is, the cluster least likely to be due to chance. Secondary clusters are also identified. Using Monte Carlo hypothesis testing, the $P$ value assigned to each cluster is adjusted for the multiple testing inherent in the large number of circles evaluated. The SaTScan option to report only clusters smaller than 10% of the population was invoked, as was the option to report only nonoverlapping clusters.

The spatial scan statistic analyses were performed unadjusted and adjusted for the child’s ethnicity (white, Asian, Hispanic, other) and census block group income (low, middle, high tertiles). For the adjusted analyses, we used the multiple data sets approach in SaTScan by using separate data files for each of the 12 race-by-income strata.

RESULTS

Study Population

The study population included 154,424 children living in the 13 Northern California counties included in the analysis (Table 1). The group was 38% white, 25% Hispanic, 22% Asian, 6% black, and 9% other or unknown. The weighted mean of the census block group median family incomes for these children was $88,200, with 9% of households having below-poverty income. Fourteen percent of adults in those census

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of children</td>
<td>42,507</td>
<td>61,684</td>
<td>50,233</td>
<td>154,424</td>
</tr>
<tr>
<td>Immunization outcomes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Underimmunized, $n$ (%)</td>
<td>3456 (8.1)</td>
<td>5689 (9.2)</td>
<td>6206 (12.4)</td>
<td>15,351 (9.9)</td>
</tr>
<tr>
<td>Shot-limiters, $n$ (%)</td>
<td>298 (0.7)</td>
<td>647 (1.0)</td>
<td>1176 (2.3)</td>
<td>2121 (1.4)</td>
</tr>
<tr>
<td>At least 1 vaccine refusal diagnosis, $n$ (%)</td>
<td>—</td>
<td>—</td>
<td>1752 (3.5)</td>
<td>—</td>
</tr>
</tbody>
</table>

* Use of refusal diagnosis codes in this health plan was rare before 2007 and so are reported here only for the 2010–2012 time period.
block groups did not have a high school degree, and 10% of adults had a graduate or professional degree. The percent of children who were underimmunized increased during the years of the study, from 8.1% in 2002–2005 to 12.4% in 2010–2012, with the percent peaking in 2010 at 13%. On average across this period, the rate of underimmunization increased annually by 5.9% (95% confidence interval [CI]: 5.2%–6.6%). For example, a rate of 10% would be followed by a rate of 10.59% the following year. When the model was run ignoring new vaccines added during the study period (to adjust for the fact that adding vaccines statistically increases the chance some will be missed), underimmunization increased by 3.4% (CI: 2.7%–4.1%) annually.

**Individual and Neighborhood Predictors of Underimmunization**

During the most recent time period (2010–2012), multivariate analysis indicated that race/ethnicity, but not gender, was a strong individual-level predictor of underimmunization. Compared with Asians, whites (odds ratio [OR]: 2.21, CI: 2.03–2.42), blacks (OR: 1.92, CI: 1.68–2.20), Hispanics (OR: 1.37, CI: 1.24–1.52), and other/unknown race/ethnicity (OR: 1.79, CI: 1.59–2.01) were all more likely to be underimmunized. Of the neighborhood characteristics, higher percent of Asians and Hispanics in the block group was associated with being fully immunized, as was higher income. Each percentage point increase in the percent of households with incomes below poverty increased the odds of underimmunization by 2.19 (CI: 1.44–3.34). Each percentage point increase in the percent of persons with graduate degrees increased the odds of underimmunization by 2.63 (CI: 1.72–4.02).

**Geographic Clusters of Underimmunization**

Among the 13 counties included in the study, in the most recent period (2010–2012), underimmunization ranged from a low of 9.2% in Santa Clara county to 17.9% in Marin County (Fig 1). The spatial analysis for this period identified 5 statistically significant clusters of underimmunized children (Fig 1). The most statistically significant cluster covered an area in the East Bay roughly from Richmond to San Leandro. Children in this cluster had 1.58 (P < .001) times the rate of underimmunization compared with children outside of that cluster (Table 2). The other clusters identified were Sonoma and Napa counties (risk ratio [RR]: 1.47, P < .001); an area between Sacramento and Roseville (RR: 1.44, P < .001); northern San Francisco and southern Marin County (RR: 1.48, P = .023); and a small area in Vallejo (RR: 1.57, P = .042).

Of the 50,233 children in the study population evaluated from 2010 to 2012, 10,144 (21%) were identified as being within a cluster of underimmunization. The underimmunization rate ranged from
17.5% to 22.7% within these clusters, compared with 10.9% outside them (Table 3). Families in the underimmunization clusters were more likely to be shot limiters and refusers and to be white than were those outside the clusters.

When the 2010–2012 underimmunization clustering analysis was run adjusting for child’s race and neighborhood income, clusters in the Sonoma and Napa counties disappeared, and the northern San Francisco and southern Marin counties remained. However, the cluster covering eastern Sacramento lost statistical significance. In addition, a new statistically significant cluster emerged in the center of San Francisco County.

**Geographic Clusters Using Alternative Benchmarks and Vaccine-Specific Analyses**

When applying the HEDIS “combination 3” definition of underimmunization for 2010–2012, the clusters were in essentially the same areas as in the primary analysis, except that they covered more of San Francisco County and smaller parts of Napa and Solano counties, and there was a newly identified cluster in western Contra Costa County. Using the HEDIS definition, 21% of children within the clusters were underimmunized, whereas 14% of children outside of the clusters were underimmunized.

Vaccine-specific analyses of underimmunization with MMR and varicella vaccines during the 2010–2012 time period showed clusters in the same general areas as the analysis of underimmunization with any vaccine (Fig 2). The most statistically significant MMR underimmunization cluster was in Marin and Sonoma counties, where children inside the cluster had 1.69 ($P < .001$) times the rate of MMR underimmunization compared with children outside of that cluster (Table 4). Similarly, the most statistically significant cluster relating to VZV underimmunization covered Marin, Sonoma, and Napa counties, where children inside the cluster had 1.94 ($P < .001$) times the rate of VZV underimmunization compared with children outside that cluster.

Analysis of shot-limiting during 2010–2012 identified clusters covering most of San Francisco, the East Bay from Berkeley to Alameda, Marin County, and southwestern Sonoma County. These areas were similar to the clusters of underimmunization during that period, except that we found no cluster of shot limiters near Sacramento or Roseville.

**Geographic Clusters of Vaccine Refusal**

The overall rate of vaccine refusal, as identified via ICD-9 codes, was 3.5% in the 2010–2012 period. Of the 50,233 children who turned 36 months of age in 2010–2012, 8933 (17.8%) resided within an identified vaccine refusal cluster. Five statistically significant clusters of vaccine refusal were identified (Fig 3): (1) East Bay from El Cerrito to Alameda (10.2% vaccine refusal, $P < .001$); (2) Marin and southwest Sonoma counties (6.6% vaccine refusal, $P < .001$); (3) northeastern San Francisco (7.4% vaccine refusal, $P < .001$); (4) northeastern Sacramento County and Roseville (5.5% vaccine refusal, $P < .005$), and (5) a small cluster south of Sacramento (13.5% vaccine refusal, $P = .033$). Vaccine refusal outside of these clusters was 2.6%. All of the vaccine refusal clusters except 1 overlapped with large parts of the underimmunization clusters and also had higher rates of underimmunization.

---

**TABLE 2 Spatial Clusters of Underimmunization by Time Period, Kaiser Permanente Northern California**

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Cluster Number and General Description</th>
<th>Radius, km</th>
<th>Block Groups in Cluster, n</th>
<th>Underimmunized Children in Cluster, %</th>
<th>Expected Underimmunized Cases, n</th>
<th>Actual Underimmunized Cases, n</th>
<th>RR</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010–2012, 1: East Bay, Richmond to San Leandro</td>
<td>14</td>
<td>627</td>
<td>18.8</td>
<td>427</td>
<td>650</td>
<td>1.58</td>
<td>&lt;.001</td>
<td></td>
</tr>
<tr>
<td>2: Sonoma and Napa</td>
<td>47</td>
<td>548</td>
<td>17.5</td>
<td>486</td>
<td>680</td>
<td>1.47</td>
<td>&lt;.001</td>
<td></td>
</tr>
<tr>
<td>3: Eastern Sacramento</td>
<td>9</td>
<td>262</td>
<td>17.5</td>
<td>196</td>
<td>278</td>
<td>1.44</td>
<td>&lt;.001</td>
<td></td>
</tr>
<tr>
<td>4: Northern San Francisco and southern Marin counties</td>
<td>16</td>
<td>235</td>
<td>18.1</td>
<td>109</td>
<td>160</td>
<td>1.48</td>
<td>&lt;.023</td>
<td></td>
</tr>
<tr>
<td>5: Vallejo</td>
<td>3</td>
<td>38</td>
<td>22.7</td>
<td>35</td>
<td>64</td>
<td>1.85</td>
<td>&lt;.042</td>
<td></td>
</tr>
<tr>
<td>2006–2009, 1: El Cerrito to Downtown</td>
<td>6</td>
<td>197</td>
<td>19.7</td>
<td>89</td>
<td>181</td>
<td>2.18</td>
<td>&lt;.001</td>
<td></td>
</tr>
<tr>
<td>2: Stockton to Merced</td>
<td>67</td>
<td>724</td>
<td>13.1</td>
<td>490</td>
<td>697</td>
<td>1.48</td>
<td>&lt;.001</td>
<td></td>
</tr>
<tr>
<td>3: Western Sonoma</td>
<td>22</td>
<td>46</td>
<td>30.3</td>
<td>11</td>
<td>57</td>
<td>3.30</td>
<td>&lt;.001</td>
<td></td>
</tr>
<tr>
<td>4: Southeastern Oakland</td>
<td>2</td>
<td>44</td>
<td>19.6</td>
<td>33</td>
<td>70</td>
<td>2.13</td>
<td>&lt;.001</td>
<td></td>
</tr>
<tr>
<td>5: Vallejo</td>
<td>5</td>
<td>71</td>
<td>14.4</td>
<td>85</td>
<td>133</td>
<td>1.57</td>
<td>&lt;.013</td>
<td></td>
</tr>
<tr>
<td>2002–2005, 1: Eastern Sacramento</td>
<td>14</td>
<td>467</td>
<td>12.2</td>
<td>233</td>
<td>350</td>
<td>1.56</td>
<td>&lt;.001</td>
<td></td>
</tr>
<tr>
<td>2: San Francisco and East Bay</td>
<td>11</td>
<td>530</td>
<td>12.9</td>
<td>107</td>
<td>170</td>
<td>1.61</td>
<td>&lt;.001</td>
<td></td>
</tr>
<tr>
<td>3: Stockton to Fresno</td>
<td>201</td>
<td>1102</td>
<td>10.7</td>
<td>263</td>
<td>345</td>
<td>1.35</td>
<td>&lt;.011</td>
<td></td>
</tr>
<tr>
<td>4: Santa Clara</td>
<td>2</td>
<td>20</td>
<td>22.7</td>
<td>10</td>
<td>27</td>
<td>2.81</td>
<td>&lt;.039</td>
<td></td>
</tr>
</tbody>
</table>

*The percent of children outside of the clusters who were underimmunized was 10.9% in 2010–2012, 8.4% in 2006–2009, and 7.3% in 2002–2005.*
than nonclustered areas. Underimmunization among children living in vaccine refusal clusters was 17.3% compared with 11.3% for children living outside of those clusters. However, among children without a vaccine refusal code, living within the geographic area of a vaccine refusal cluster was not associated with higher odds of being underimmunized (OR: 1.06, CI: 0.98–1.17).

**DISCUSSION**

**Major Findings**

Underimmunization and vaccine refusal cluster geographically, and the rates of these outcomes within clusters are far higher than outside them. The existence of clusters may put clinical groups in these locations at a disadvantage in achieving immunization quality benchmarks. The use of spatial scan statistics to identify emerging clusters of underimmunization or vaccine refusal may enable clinicians and policy makers to focus efforts to increase vaccination coverage in specific geographic areas. A recent study found that nonmedical exemptions from immunization in California clustered geographically and were associated with clusters of pertussis cases. Many previous studies have found that vaccine refusal and delay are associated with elevated risk of measles and pertussis outbreaks, as well as elevated individual risks of measles, pertussis, varicella, and pneumococcal infections. Meanwhile, a recent study found that parental vaccine acceptance was higher when physicians used communication approaches that assumed parents would accept all recommended vaccines. Clinic- and Web-based interventions to reduce vaccine hesitancy are being tested.

This study is novel in that we were able to describe clusters of shot limiting and vaccine refusal and found that these were highly consistent with clusters of underimmunization. The use of alternative immunization schedules has increased in recent years. Our finding that underimmunization increased in children born between 2000 and 2011 in Northern California agrees with an earlier analysis in this and other populations that found underimmunization increased among children born between 2004 and 2008. Our analysis goes beyond current studies in that we found that spatial scan statistics could be used to identify incipient clusters of shot limiting and refusal. Thus, spatial scan statistics may be a useful tool to
identify locations that deserve increased public health and clinical attention.

One practical implication of our findings is that it may be more challenging for physician groups in communities with high rates of shot limiting and vaccine refusal to achieve high immunization coverage rates. Because these rates are used in national quality metrics, some physician groups are at risk for being evaluated as delivering lower-quality care based in part on factors that may arise from the social environment.

Limitations

The study population of Kaiser Permanente members included Medicaid-insured children but not

![FIGURE 2](image.png)

Clusters of (A) MMR and (B) varicella underimmunization, Kaiser Permanente Northern California, January 2010 through December 2012.
uninsured children. The study population was racial/ethnically diverse, although it had higher representation of Asians and whites and lower representation of Latinos compared with similarly aged children in the California general population. Vaccine refusal was evaluated by using diagnosis codes, and there is likely some inaccuracy and variability among providers in their use.

While we were able to identify geographic clusters, we did not have additional data to explain why they arose. Our analyses adjusted by race/ethnicity and neighborhood income suggested that these were not dominant drivers of clustering, although individual-level underimmunization was higher in neighborhoods with more families in poverty, as well as those with more graduate degrees. Future analyses of internet use or social media might provide further insight about what drives geographical clustering.

**CONCLUSIONS**

Underimmunization and vaccine refusal cluster geographically. The rate of vaccine refusal in some communities may pose barriers for local clinical groups to achieve national quality benchmarks for vaccine coverage. Spatial scan analysis is potentially useful for early identification and monitoring of emerging clusters of underimmunization and vaccine refusal.

**ACKNOWLEDGMENTS**

We are grateful to Eve Wittenberg, ScD, Cathy Chou, MS, Adrianna Sanna, MPH, and Brian Zikmund-Fisher, PhD, our collaborators in the Parent Preferences for Immunizing Children project, for their support and guidance of this work. We thank Karen Silva for her excellent assistance with this manuscript.
REFERENCES


20. Robison SG, Groom H, Young C. Frequency of alternative immunization

Address correspondence to Tracy A. Lieu, MD, MPH, Division of Research, Kaiser Permanente Northern California, 2000 Broadway, Oakland, CA 94612. E-mail: tracy.lieu@kp.org

PEDIATRICS (ISSN Numbers: Print, 0031-4005; Online, 1098-4275).

Copyright © 2015 by the American Academy of Pediatrics

FINANCIAL DISCLOSURE: Dr Klein receives research support from Merck, GlaxoSmithKline, MedImmune, Novartis, Pfizer, Sanofi Pasteur, and Nuron Biotech; the other authors have indicated they have no financial relationships relevant to this article to disclose.

FUNDING: Supported by a Patient-Centered Outcomes Research Institute Pilot Project contract.

POTENTIAL CONFLICT OF INTEREST: Dr Klein receives research support from Merck, GlaxoSmithKline, MedImmune, Novartis, Pfizer, Sanofi Pasteur, and Nuron Biotech; the other authors have indicated they have no potential conflicts of interest to disclose.

YOU SAY POTATO: My wife and I like many of the same food groups, and she seems quite happy to eat whatever I happen to cook for our evening meal. Our preferences are a bit different, however. She prefers pasta over rice (despite my fantastic selection of different types of rice) and absolutely adores potatoes of all types. I tease her that she has yet to meet a potato that she does not like. I am curious, however, what she will think of a new genetically modified potato that has just been approved for commercial planting by the Department of Agriculture. As reported in The New York Times (Business Day: November 8, 2014), the new potato is less prone to bruising and produces less acrylamide when fried. Bruising is important to growers and packers as bruised potatoes are less valuable and may not even be marketable. Acrylamide is a chemical that causes cancer in rodents and is a suspected human carcinogen. However, no one is quite sure what level (if any) of acrylamide in food groups is dangerous. After cooking, acrylamide levels are 50-75% lower in the genetically modified potato than in conventional potatoes. Whether the new potato will be commercially successful is unclear. In the 1990s, potatoes genetically modified to resist the Colorado potato beetle were a commercial failure due to consumer resistance. Still, these new potatoes may be more easily accepted by consumers as no foreign genetic material is used in these spuds. The genetically modified potatoes contain pieces of potato DNA that silence four genes involved in the production of specific enzymes. Given the intense battles in state legislatures and in food stores regarding labeling of genetically modified foods, it may take time for the new potato to find a market. I doubt I will find many of the new potatoes for sale in Vermont. If I do, however, I will buy some and ask my wife to participate in a blind taste test.

Noted by WVR, MD
Geographic Clusters in Underimmunization and Vaccine Refusal
Tracy A. Lieu, G. Thomas Ray, Nicola P. Klein, Cindy Chung and Martin Kulldorff

*Pediatrics*; originally published online January 19, 2015;
DOI: 10.1542/peds.2014-2715

The online version of this article, along with updated information and services, is located on the World Wide Web at:
/content/early/2015/01/13/peds.2014-2715