What is the role for policy in the private decision to vaccinate children?

Advancing Immunity

BY RENEE COURTOIS

Ten years ago the United States declared that widespread transmission of the measles — one of the world's most infectious diseases — had been eliminated. No small feat considering that 50 years ago virtually everyone in the United States got the disease before the age of 20. As many as 4 million Americans contracted the disease each year; 400 or 500 died, while about 48,000 were hospitalized and 1,000 left with chronic disabilities like brain damage or deafness.

Vaccinations are at the root of this dramatic improvement. Nowadays, most years see about five dozen cases of the measles in the United States. In 2008, the year-end total of a mere 140 cases was the worst in years. As with all modern-day outbreaks, the disease was imported from foreign visitors to the United States or from U.S. residents who traveled abroad and acquired measles in other countries experiencing outbreaks. Once in the United States, 90 percent of infected people had not received the measles vaccination or their vaccination status was unknown, according to the Centers for Disease Control and Prevention.

Though small in relative terms, recent outbreaks are a reminder that containment of vaccine-preventable diseases depends critically on the number of people in the population who choose to get vaccinated. If enough people are immunized, they collectively create "herd immunity" — with sufficiently few susceptible people in the population, the disease is unable to spread, protecting those who are not vaccinated by medical necessity, choice, or because they are too young.

That rate is determined by a mathematical formula based on factors including the vaccine's rate of failure and how easily the disease is transmitted. Professor Matthew Davis at the University of Michigan says the rule of thumb is that it takes about an 80 percent vaccination rate against a disease to provide herd immunity to the other 20 percent. But for a highly infectious disease like the measles — which will infect nine of 10 susceptible people who come into contact with it — as much as 95 percent of the population must be vaccinated to provide herd immunity.

About 67 percent of children aged 19 to 35 months receive the broadest set of vaccinations recommended by the CDC, according to the latest data available. Though below the 80 percent mark, herd immunity is not necessarily threatened since vaccination rates are much higher for each individual disease. For example, Idaho, the state currently with the lowest total vaccination rate, still enjoys coverage above 80 percent for most vaccines. By and large, it is the case that most children receive most vaccines.

But that's for the nation as a whole; there are pockets of the country — sometimes as narrow as the community or school level, for which data are scarce — with a relatively higher rate of unvaccinated individuals. "That suggests there are areas that are more at risk of getting these vaccine-preventable diseases than others," says Davis. In some schools, as many as 15 percent to 20 percent of students are unvaccinated. Modern measles outbreaks tend to be concentrated in unvaccinated populations, such as members of the same religious congregation or young classmates in communities where a culture of natural medicine is prominent.

The reasons behind widely different vaccination rates across regions are not entirely understood by the health care community. One clear part of the explanation is that requirements differ dramatically across states (vaccine recommendations can be enforced only at the state level). According to the Centers for Disease Control, all states require vaccinations against diphtheria, tetanus, pertussis (whooping cough), polio, and measles prior to kindergarten entrance through 12th grades. States have mixed vaccination requirements for other diseases, such as mumps (47 states plus Washington, D.C.), and varicella or chickenpox (44 states plus D.C.), among others.

But all states allow for exemptions that permit a child to attend public school unvaccinated. Medical exemptions, such as an allergy to a component of the vaccine, are allowed in all states, though well under 1 percent of children fall into that category. Religious exemptions are allowed by 48 states and Washington, D.C. — West Virginia and Mississippi are the exceptions — and 20 states allow philosophical exemptions.

The ease of being granted an exemption also is a factor. Some states

Marked Improvement

New cases of many diseases have fallen dramatically since vaccines were introduced, though experts note that some diseases, like pertussis, are on the rise.

	Measles*	Mumps*	Pertussis* (Whooping Cough)
1950	211.01	N/A	79.82
1960	245.42	N/A	8.23
1970	23.23	55.55	2.08
1980	5.96	3.86	0.76
1990	11.17	2.17	1.84
2000	0.03	0.13	2.88
2009	0.02	0.65	4.40
Date Vaccine Introduced	1963	1967	1949

*Per 100,000 people in population

NOTE: A national measles outbreak spanning 1989-1991 boosted new case numbers for 1990.
SOURCE: Centers for Disease Control and Prevention. Data for 2009 calculated by author using CDC and Census data.

require only a signature on a form, whereas others require notarized personal statements, annual reviews, and input from local health officials. A 2006 study in the *Journal of the American Medical Association* (JAMA) found that exemptions doubled between 1991 and 2004 in states with a relatively easy exemption process, with no obvious increase occurring in states with a harder exemption process. The study found that states with a stricter exemption process had lower rates of exemptions and, consequently, lower incidence of the diseases in question.

The Costs and Benefits of Vaccinations

Vaccines are heralded as one of the single greatest public health triumphs the world has seen. Thanks to vaccines, deadly and debilitating diseases have been kept at bay, virtually wiping out the incidence of illnesses such as mumps, polio, and measles. This has freed health professionals to focus on chronic diseases like cancer. The demonstrated effectiveness of vaccines in preventing disease clearly provides an individual with an incentive to get vaccinated.

Vaccines work by injecting the body with a mild or dead form of a virus, providing the immune system the opportunity to figure out how to attack it. The immune system has a memory: If ever again confronted with the disease, it will recall the blueprint to the antibodies. Edward Jenner discovered the method in the 18th century when he observed that milkmaids rarely contracted the deadly smallpox disease, which he hypothesized was because they contracted the less-virulent version that afflicted cows. Their bodies were able to fend off cowpox and establish immunity to smallpox in the process.

Despite proven benefits of vaccinations, some parents choose not to vaccinate their children. One reason is that vaccines are a victim of their own success: As diseases like measles and polio decline in numbers or are eradicated, so dies the memory and fear of them. And in many states the exemption process is less burdensome than actually getting the many required rounds of vaccinations viewed by some parents as excessive.

Financial costs are an impediment, sometimes leaving areas with many low-income families vulnerable. Vaccines are funded through a mixture of private and public sources. For those with health insurance, differing state regulations mean insurance coverage of vaccines varies. Few state regulations mandate national recommendations as a guide, though, and the skyrocketing expense of the full recommended regimen of vaccines increasingly means that many are not covered by insurance.

Public assistance is available for children not covered or underinsured. The U.S. government under President Clinton enacted the Vaccines for Children program that subsidizes child vaccinations for the vast majority of children whose private insurance doesn't cover them. A growing number of states also have "universal purchase" programs in which the state purchases and distributes vaccines to both public and private immunization providers at lower prices.

Despite such steps, financial barriers persist. Families often don't know they're covered by government programs, according to Davis, and that has limited their success.

But parental fear of vaccine safety is by far the largest stated reason for avoiding vaccinations. Nearly one in eight parents refuse at least one recommended vaccine, according to Davis and coauthors in a 2010 study, especially newer vaccines for chicken pox and human papillomavirus (HPV). One in five believes some vaccines can cause autism in otherwise healthy children.

Interestingly, it's not that such parents think vaccinations are ineffective; even vaccine refusers overwhelmingly believe vaccines are able to prevent disease, according to Davis and his coauthors. It's that they think vaccinations may be more harmful than the diseases they prevent, given the low probability of catching them.

Experts say the risks from vaccines are small. Mild reactions are common — about one in four children experience low-grade fever following the diphtheria/pertussis/tetanus (DPaT) shot, for example — but severe reactions are very rare. One in 1 million children will experience seizures or brain damage after the DPaT shot. Severe effects are so rare that it is hard to know if they're caused by the vaccine, according to the CDC.

Experts view the parental fears of such small risks as a major threat to public health since they have led to decreased vaccination rates and subsequent outbreaks in other countries. After a study linking the MMR vaccine to autism — a study that was discredited and retracted earlier this year — was published in a British journal in 1998, MMR vaccination rates in England dropped over 10 percentage points in six years. England saw 56 measles cases in 1998, and by 2008 there were 1,370. A similar story occurred in the northern region of Nigeria after people shunned the polio vaccine out of AIDS and other concerns. Following a rapid resurgence of polio in that country, experts say immunization against polio in Nigeria is in danger of failing.

The lesson is that as immunization rates fall, there can be a tipping point at which even the vaccinated face increased risk since no vaccine is perfectly effective, and diseases start to dramatically resurge. But where that tipping point is, experts aren't sure.

Guiding Vaccination Policy

In the matter of vaccinations, there is a natural tension between self-interest and public welfare. How should policymakers weigh public health with private freedom concerning health choices? Researcher Alison Galvani of Yale University and various colleagues have developed game theory models in which an individual's choice depends on the strategies chosen by others. They used these models to analyze the vaccination rates that could prevail under a purely voluntary vaccination policy regime compared to vaccination rates that would maximize

the welfare of the population as a whole.

If the decision to vaccinate was left purely up to self-interest, individuals (and parents, in the case of a child) would decide whether to vaccinate based on their perception of the costs and benefits of doing so. But if everyone else is immune, a vaccine poses little individual benefit. For individuals who view vaccines as especially risky or the risk of disease as low, their best choice will be to go without. Therefore, in the Nash equilibrium — a game theory outcome in which no individuals can improve their lot given the strategies chosen by others — the total vaccination rate is likely to be lower than socially optimal.

The outcome, in this case, would be greater illness since a nonimmunized person is more likely to catch and spread the disease. This meshes with empirical studies: Several have found that communities with lower vaccination rates had higher infection rates even among vaccinated children.

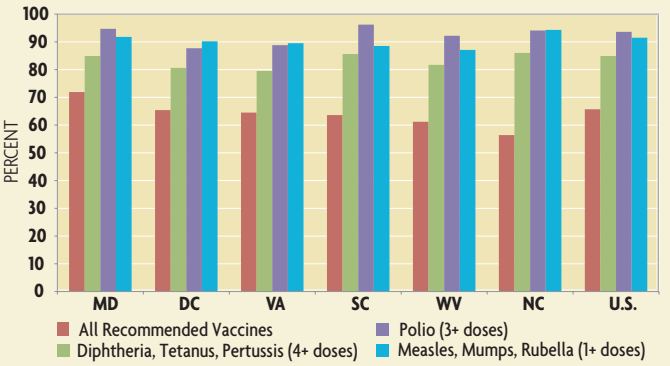
The utilitarian approach is arguably more characteristic of the vaccination policy we have today: Vaccine mandates are intended to maximize the welfare of the entire population, at least where disease control is concerned. School mandates have been by far the most effective way to increase vaccinations. However, some requirements test the limits of public tolerance for sacrificing freedom for the greater good like the newer adolescent vaccines for sexually transmitted diseases that have proven unsavory to many parents.

Exemptions are a way to modify the utilitarian approach to allow a greater scope for private preferences. But they undermine the benefits provided by mandates since exemptions provide an opportunity to "free ride" off the immunity of the herd, just like in the Nash equilibrium. Those exempted get the benefits of immunity through the herd without the hassle, financial costs, or perceived risks of vaccination.

Both strategies seem to imply that policy should also focus on directing private choice toward the optimum; that is, to bring the Nash and utilitarian outcomes closer together through strategies that increase voluntary vaccinations. This means understanding people's decisions not to vaccinate and improving accurate public information about the costs, benefits, and administration of vaccinations. This could be particularly helpful concerning the risks that a vaccine poses for a given individual, since those fears are one of the biggest current threats to herd immunity and have led to reduced vaccine uptake and outbreaks in the past.

Fifth District Coverage

Percent of children aged 19 to 35 months receiving all recommended dosages for select vaccines



SOURCE: Centers for Disease Control and Prevention, 2008 National Immunization Survey

Research indicates that the people most trusted to convey information about vaccine safety are doctors. So Davis suggests that any efforts to address the public's concerns over vaccine safety have to involve individual physicians to be effective. There's risk with any procedure or medication, he says, but it's hard to know whether a given individual will experience side effects as he or she receives something for the first time. "For some people the vaccine safety concerns are outweighing the possible benefits in their minds, and that's a very important conversation that doctors need to have with patients and parents."

If all else fails, Galvani and her colleagues suggest that policymakers shouldn't discount appealing to altruism as a way to increase voluntary vaccinations. Parents aren't always conscious that the private vaccination decision has public consequences, according to Davis. He says parents who are inclined to refuse vaccines often ask why they should give the polio vaccine, for example, to their children when chances are imperceptibly small they'll catch the disease.

"My answer to them is, 'Why do you think your child is not likely to get polio?' They pretty quickly get to the fact that their children are protected only because other parents have vaccinated their children against polio." No parent, he says, enjoys realizing their children would be free-riding on the immunity of other children. **RF**

Christina Zajicek contributed to this article.

Readings

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