

FOCUS: VACCINES

Understanding Vaccines: A Public Imperative

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Though once a discovery greatly celebrated by the nation, the vaccine has come under fire in recent decades from skeptics, critics, and a movement set into motion by fraudulent scientists and fueled by frustrated parents looking for answers to the autism conundrum. There is enough denialist resistance to vaccination to bring upon renewed fear of young children and infants becoming infected with diseases, the threats of which had been functionally eradicated from the United States. In more recent years, the surge in independent online journalism and blogging has invited many to rapidly share their opinions with millions of readers and, importantly, has appeared to open the door for opinion to be portrayed as fact. As a result, many parents are inundated with horror stories of vaccine dangers, all designed to eat away at them emotionally while the medical and scientific communities have mounted their characteristic response by sharing the facts, the data, and all of the reliable peer-reviewed and well-cited research to show that vaccines are safe and effective. It has become clear to me that facts are no match for emotion, but perhaps an understanding behind vaccine methodology will help parents overcome these fears of vaccinating. By helping those who doubt vaccines better understand what vaccines really are and how they work in such an incredibly engineered fashion, we may have a stronger weapon than we realize in battling the emotional arsenal that comes from the fear and skepticism of vaccinating.

INTRODUCTION

The anti-vaccination movement is today perhaps one of the most mind-boggling and frustrating situations facing doctors, biomedical researchers, nurses, and almost anyone in the health care field. Vaccines are a truly remarkable example of mankind's ability to understand the biological world around us and within us and to use that knowledge to better preserve the

health and life of our species. They allow us to engage our adaptive immune systems to produce highly specific antibodies and immunological memory against a potential future infection. In practice, vaccines are most often comprised of an attenuated or weakened version of a particular pathogen. Importantly, this attenuation is accomplished in such a fashion that it renders the pathogens incapable of inducing an infec-

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†Abbreviations: MMR, measles, mumps, and rubella.

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tion, while still being sufficiently intact for our immune systems to recognize them as foreign. Other vaccines may often incorporate only components of a particular pathogen. The components on their own are, again, insufficient to induce infection but are still processed by our immune systems as if an infection were present. The result is that the actions our immune system takes in response to these attenuated pathogens or simply their components are normally reserved for when our bodies face the potentially quite harmful first presence of the true or wild-type pathogen, yet we have developed a system to introduce the protection afforded to us without having to risk the initial exposure [1]. But how have we found ourselves in a situation where increasing numbers of parents are opting out of one of the most powerful medical treatments ever to be created by man? Indeed, vaccines are an astounding accomplishment, yet much of their efficacy relies on usage at a population level, offering herd immunity, whereby even those offered less protection from a particular vaccine, or who may be allergic or otherwise unable to receive a vaccine, may still be protected because they are surrounded by a community far less capable of harboring an epidemic in totality [2]. This introduces a dangerous paradigm where “opting out” no longer only affects the particular parents and children in question, but their friends, relatives, neighbors, and, in all reality, a far greater portion of the human population than one may realize. It is primarily for this reason that it has become crucial that we do our best to fight the anti-vaccination movement. The “your loss” attitude is invalid; rather, our communities, societies, and species as a whole may be at greater risk when someone decides to not vaccinate against a potentially deadly disease.

Indeed, one can find several instances since the advent of vaccinations whereby reduced vaccine usage has been followed by increased epidemics of a particular disease. Recently, refusal of parents to vaccinate their children has been heavily implicated in the ongoing mortality associated with pertussis epidemics in the United States [3], and

reduced numbers of children vaccinated against measles has been suggested as a major contributing factor to some of the highest numbers of measles cases reported in the United States in decades [4].

In a day and age where ideas and opinions spread from computer screen to tablet to smart phone like wildfire, and where self-publishing has become a daily routine, the anti-vaccination movement has been and is still being fueled on a regular basis by outspoken celebrities whose children suffer from autism and a growing number of “naturalists” who believe that mankind was simply not meant to meddle in the affairs of our environment, and thus how we are affected by disease. It is important to keep in mind that the average reader of Facebook pages, *Huffington Post* articles, and Twitter comments is likely not looking for references. The dissemination of opinion as fact could be considered its own epidemic and may be playing a large role in swaying many on-the-fence parents into the anti-vaccination movement.

While there will always be a small portion of fervent conspiracy theorists and science deniers holding down the anti-vaccination fort, from the conversations I have had with acquaintances who choose not to vaccinate their children and the endless comments I have read online in forums, it has become clear that many simply do not understand vaccines. They do not know how vaccines work, making them susceptible to pure fiction regarding the subject and may be therefore inappropriately criticizing vaccine usage due to these misunderstandings. It is imperative that we do all what we can to dispel these rumors and educate the public on what vaccines truly are. Fact after fact has been thrown at the anti-vaccination movement to no avail. I propose that we instead do our best to creatively educate and illustrate how vaccines function. While this concept may be more familiar to those of us with training in immunology and microbiology, we must find a way to translate this into something that one with any educational background can understand. I posit that many of the parents who are currently being convinced to deny vaccine usage would be just as easily convinced to uti-

lize them if they had a reason *that makes sense to them*.

WHEN FACTS WON'T SUFFICE

While it may be hard for us to imagine, facts are simply not enough to convince vaccine deniers of their safety or efficacy. Time and again, article after article has shown that there is indeed no significant link between vaccine administration and incidence of autism, for example. The most recent “study of studies” examined data from some 1.2 million children to draw these conclusions [5], while the original conclusion from the infamous Wakefield study was based on “data” from only a handful of self-reported cases. I would cite that article as well if it hadn’t been retracted for numerous reasons.

Yet with all the data showing that the original link between the measles, mumps, and rubella (MMR†) vaccine and autism is simply not true, many parents choose to believe it nonetheless. Perhaps this association has remained such an intriguing concept for parents of autistic children because autism is often diagnosed at the ages when many vaccinations are administered. Furthermore, with no clear answers as to why so many children are developing autism, that idea, once proposed but later deemed a fallacy, may tend to stick in the minds of those looking for answers until a more viable conclusion has been drawn. While the Centers for Disease Control may publish numbers, facts, figures, and any other reassurances regarding vaccine safety, much of this is unfortunately falling on deaf ears. It is important to remember that most vaccine deniers may be reading literature that is portrayed as fact but is no more than one journalist’s opinion. The scientific and medical communities greatly value the concept of referencing peer-reviewed publications. There is a trust among fellow researchers that articles, which for lack of a better term “survive” the review process, have been carefully examined and deemed to accurately reflect the findings or conclusions based on data either referenced or directly presented. It can be quite daunting, however, for someone out of practice or

never trained in critical literature review to be able to parse apart peer-reviewed publications from opinion articles. I have been delighted to see some science-minded bloggers post articles intending to teach others how to read online posts and critically examine them for validity. As you might imagine, looking for references was a major takeaway. If everyone were trained to look for references and take that into account when judging the validity of what they just read on anyrandomguysopinionsonvaccines.com, perhaps there would be a great deal less confusion and controversy over what many would consider a moot point.

It seems reasonable that we should expect some form of review process for articles published online, but we simply cannot. These are often opinion website or pages, and it is up to the reader to not only look for references, but to judge the validity of each reference and the conclusions made by the author from those references. Moreover, the Internet has led to an explosion of available opinion and editorial content. Being published is far more common than it ever has been, and more and more self-publishing writers can say anything online without having an editor to keep them grounded. To overcome these challenges, we must strive to teach future generations how to think critically about the information in front of them, draw their conclusions in a logical fashion, and engrain these concepts in early education so we may truly promote analytical thinking and sound methods of literature research from a young age.

THE IMPORTANCE OF BASIC UNDERSTANDING AND TEACHING THROUGH ANALOGY

The lack of knowledge on how vaccines function is not mutually exclusive to the misinformation regarding vaccine safety and autism. This is where I believe we can cover the most ground in defense of vaccination practices. With the ever-growing abundance of medical procedures, prescription and over-the-counter drugs, and other medical treatments, it is easy to imagine that much

confusion may lie in the subtle differences between them. For example, vaccines may often be confused with an antiserum, the latter of which consists of pre-formed antibodies taken from another organism to be injected into your blood stream, thus offering you temporary protection in a passive manner. This is in contrast to the active and memory-inducing processes afforded by vaccines. Furthermore, while vaccines are given to prevent certain infections, antibiotics are often given to treat very similar infections once they have occurred. Without knowing their mechanisms of action, however, the above association may lead to one's conflation of these treatments. In contrast to vaccines, antibiotics are chemicals that actively kill bacteria in your body, independent of your immune system and in an autonomous manner. It is crucial that we make more of an effort to clarify that vaccines and our own immune systems are working *together*. In fact, this cooperation is so deep that a vaccine would be completely and utterly meaningless as a preventive measure in someone lacking a functional adaptive immune system. Antibiotics and antisera, however, are among the only options for those individuals. Thus, while these and many other medical treatments work independently, vaccines work together with our immune systems, a subtle difference that may not be entirely clear to most outside of the biology and medical fields yet is a crucial distinction in truly understanding what a vaccine is.

So how do we really teach the public about what vaccines are and how they work? How can we explain these concepts when the immune system seems to be most commonly discussed in the context of films featuring fictitious zombie viruses? I believe the answer lies in creative lessons involving analogies, which can be very powerful tools to break down complex concepts and situations into a palpable and somewhat accurate description. Although this is not a simple vision, the right analogy or simple explanation can clear up a great deal of understanding, and I feel that taking the time to develop creative ways of explaining how vaccines work

will ultimately help the scientific community get these concepts across to the general public.

VACCINES: THE ENEMY?

Below is an analogy that I often use to explain how vaccines work. It may provide a basic framework for how to effectively communicate the nature of scientific concepts through imagery already familiar to the reader.

Imagine pathogens being a literal enemy, a foreign country constantly threatening to invade our soil. Depending on where the listener stands on the issue, this may come quite naturally to them. Now, let's say that the threat of invasion by this foreign country appears quite likely. As to not offend any potential readers, we'll call it the fictional land of West Xylophone. Lately, West Xylophone has gone from country to country, often completely destroying whole nations and certainly crippling, paralyzing, or leaving the surviving lands in ruins. Given this new threat, our first instinct would be to gather some military intell and reconnaissance. This makes sense right? A new enemy is out there, invasion may be imminent. If we only knew the types of weapons they were harboring, tactics being employed, uniforms that they wore, even what they look like, we would be infinitely better prepared to fend off the invasion.

Now imagine that it were possible to take away all of the enemy's ammunition yet still trick them into believing that they were in fact fully armed and invading our soil with all genuine hostility. What amazing intell that would be, perhaps the most ideal information to have in a war situation. We can immediately answer so many questions: How do they approach their missions? Where do they set up camp? Are they digging trenches? Flying bombers over major cities? What are their tools, their tricks? This one-sided simulation would give us an astounding edge if or when an actual invasion was to take place.

Enter the vaccine, a way for our bodies to see firsthand how a particular pathogen

will invade us, what it looks like, where it tends to reside, be it within our cells like viruses or floating throughout the blood stream like many bacteria and toxins. And, of course, all of this is being accomplished as nothing more than an almost no-risk learning experience. Vaccines allow us to see the enemy and learn almost everything we need to know in order to fend off a future attack, a real attack, one fully armed with weapons and capable of utter annihilation. Would you get the same intell if the pathogen actually invaded, weapons blazing, and you were able to fight it off successfully? Of course, but you'd have to survive that first invasion, and who knows the extent of the damage that would be left behind? When you know that this is one of those few intruders, so strong, so potentially life-threatening that upon first contact you may perish, it should be an easy choice to get the vaccine and give this priceless information to your immune system. At the end of the day, after being vaccinated, it is still your own body, your own immune system offering you protection; the only difference is that those who get vaccinated have well-prepared, well-trained, and incredibly well-equipped immune systems versus those who eschew the vaccine concept simply because of unfounded alarmists and propaganda.

CONCLUDING REMARKS

I propose that educating vaccine deniers on the molecular nature and methodology behind vaccine design and function, even in a simplistic way, will be our best avenue as a scientific community to quell the spread of rumor and anti-vaccination excitement that has become so prevalent. It is clear that facts regarding the safety and efficacy of vaccines simply do not persuade everyone, but it is my hope that an appreciation for their amazing power, through the understanding of their design and methodology, may help convince many of why the medical and scientific community so actively supports their usage.

It is important to keep in mind the historical context of vaccines, as well as meas-

ures such as these, were not always necessary. For years, families lived through the polio epidemic, fearing for their lives and limbs every summer, never knowing if they would be the next to fall ill with such a horribly debilitating disease. When Jonas Salk introduced the first functioning polio vaccine approved for public use, he became a national hero. The current generation of new parents has never experienced this fear, and therefore is unacquainted with the relief of eradicating a horrible disease with a new vaccine. Without this experience, it has become much easier to become so critical of vaccination. An experience such as this for younger generations would mean the health and lives of far too many to want to imagine. Rather, we should ensure that these moments in history are taught to younger generations. We should teach and reinforce the history of man's war against pathogens similarly to how we educate the young on man's wars against himself. Hopefully, the passing on of this knowledge will quell the potential of history to need to repeat itself.

Finally, there are yet others who will never be convinced. There will always be a small population of individuals who maintain their tenacious conviction against vaccination practices. For instance, a conversation on the subject with a distant relative of mine ended shortly after she told me, "Well sure, maybe everything you're saying is true ... if you believe in science." Addressing that last point any further would certainly venture outside the purview of this article, but it is important to acknowledge that in spite of this, we must continue to educate the less fervent but perhaps just misinformed populations in order to gain back herd immunity to the extent that we no longer face the threats of preventable disease.

While the most extreme vaccine deniers may never choose to believe that they are safe and effective or care to understand how or why they work, it is the more malleable conclusion drawer that we as doctors and scientists must do our best to educate. It has been my experience that often the odd biases that I encounter are not deeply rooted in

some tenacious conspiracy theory beliefs, but rather that many simply do not know what to believe. There is an enormous array of online articles published containing nothing more than lies and falsehoods regarding vaccines. So much so that many have become confused and overwhelmed. A recent study concluded that having more information regarding the safety and efficacy of vaccines did not affect the rates of vaccine administration. In fact, having more knowledge about the disease itself seemed to cause *fewer* parents to vaccinate their children [6].

While much hope may be lost when studies of this nature are published, it is important to note that the information given to the parents in this particular study regarded only safety and efficacy figures, as well as the true dangers of the disease itself. This is quite different from an explanation or definition of what a vaccine is at a fundamental level. As scientists, we value rational conclusion drawing, and we are not quick to accept data without seeing a logical mechanism or other explanation. I question then why we have been trying to answer the vaccine deniers with only safety and efficacy data while not doing our best to convey the mechanism of vaccination. Until we do, we cannot reasonably expect to see changes in the attitudes of vaccine deniers. Rather than spouting off fact after fact to simply counter the notions that vaccine deniers carry regarding their safety or efficacy, try to teach them. Teach them not that they are wrong to believe that vaccinating is dangerous and not worthwhile, but teach them what a vaccine truly is. Teach them that vaccines are not antibiotics, that they are not doing something instead of allowing your own immune system to go to work. Teach them how they are preparing your immune system to recognize the few deadly and infectious diseases out there that may be life threatening or debilitating at a young age. Teach them that vaccines are forms of train-

ing for your immune system, not crutches that will weaken your body's ability to protect itself, but rather crucial intelligence that will provide the guidance and preparation that your body needs to fend off subsequent attacks. And finally, teach them that vaccines do not combat the activity of your immune system but rather work with it in a very profound and productive manner. It is always easier to be critical of vaccine deniers, to judge and to speak down to them, but keep in mind that most simply were never taught what a vaccine actually is. Over the past century, we have witnessed a dramatic reduction in cases of serious illness caused by many diseases due to the advent and practice of vaccination. We must all do our part to maintain this crucial herd immunity and protection that vaccines have afforded us. To see the return of preventable epidemics due merely to a lack of public understanding of the vaccination process could only be considered a tragic regression.

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