Open Forum Infectious Diseases

REVIEW ARTICLE

Vaccine Rejection and Hesitancy: A Review and Call to Action

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Vaccine refusal has been a recurring story in the media for well over a decade. Although there is scant evidence that refusal is genuinely increasing in the population, multiple studies have demonstrated concerning patterns of decline of confidence in vaccines, the medical professionals who administer vaccines, and the scientists who study and develop vaccines. As specialists in microbiology, immunology, and infectious diseases, scientists are content experts but often lack the direct contact with individuals considering vaccination for themselves or their children that healthcare professionals have daily. This review examines the arguments and players in the US antivaccination scene, and it discusses ways that experts in infectious diseases can become more active in promoting vaccination to friends, family, and the public at large.

Keywords: antivaccination; internet; misinformation; vaccine denial; vaccine hesitancy.

Since the late 1990s, concern has grown regarding a resurgence of the "anti-vaccine movement," a loosely defined group of individuals who sow doubt about the effectiveness and safety of vaccines. Although the most current iteration of this scare can be traced to the publication of Andrew Wakefield's (since-retracted) paper linking the measles-mumps-rubella (MMR) vaccine to autism in 1998, anti-immunization sentiment in reality predates the process of vaccination, dating back to objections to the process of variolation in the early 18th century to reduce smallpox morbidity and mortality [1, 2].

Although vaccine rates have remained high in the United States as a whole [2, 3], national surveys can overlook pockets of vaccine refusal that exist in many communities [4]. Areas with low vaccination rates have resulted in localized outbreaks of vaccine-preventable diseases, including measles and pertussis [5]. Measles cases in the United States reached a 20-year high in 2014 [6]; 90% of those were among individuals who had not been vaccinated or whose vaccination status was unknown [6, 7], suggesting the unvaccinated are drivers of outbreaks. Furthermore, vaccines are victims of their own success. Today, even many physicians have not seen a case of measles, diphtheria, or other vaccine-preventable diseases; parents are a generation more removed from the scourges that polio and rubella represented. As such, antivaccine activists have been able to describe these diseases as harmless consequences of childhood, and vaccines are presented as the danger rather than the disease. Although public health and medical practitioners have been concerned about increasing antivaccine sentiment, programs that have been implemented to change minds and attitudes have been largely ineffective [8, 9].

This review aims to (1) provide infectious disease experts with grounding in the current rhetoric of vaccine denial, (2) introduce the cast of characters who play a role in perpetuating vaccine misinformation and driving vaccine fear, and (3) discuss ways scientists can respond in various venues to demonstrate support of vaccines and the very principles of vaccination.

THE ARGUMENTS

The arguments against vaccination have changed little over time [1, 2]. These are summarized in Table 1 and will be discussed here briefly. Most objections to vaccination are currently cached in language that makes them highly palatable to parents and difficult for scientists to object to, using terms such as "informed consent," "health freedom," and "vaccine safety" [10]. A recent article in *Natural Mother Magazine* makes it explicit that antivaccine advocates should use language that frames vaccines as dangerous or unnatural, substituting "vaccine-free" or "intact immune system" for "unvaccinated", and "vaccine-associated diseases" instead of "vaccine-preventable diseases" [11], for instance.

Many of the arguments focus on areas of distrust in medical science. They advance the notion that vaccines are "unavoidably" dangerous because of nebulous "toxins" introduced into the body via vaccination. Some of these chemicals are present in small amounts (aluminum as an adjuvant, for example); others, such as "antifreeze," are not and never have been present

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Table 1. The Arguments

Vaccines are "toxic" and contain antifreeze, mercury, ether, aluminum, human aborted fetal tissue, antibiotics, and other dangerous chemicals that can lead to autism and an assortment of chronic health conditions. Slogan: "Green our Vaccines".
Vaccines are a tool of "Big Pharma;" individuals who promote them are merely profiting off of harm to children and/or paid off by pharmaceutical companies ("Pharma shills").
A child's immune system is too immature to handle vaccines; they are given "too many, too soon" and the immune system becomes "overwhelmed," leading to autism and an assortment of chronic health conditions.
"Natural immunity is better;" most vaccine-preventable diseases are harmless to most children, and natural exposure provides more long-lasting immunity. eg, "I had the chickenpox as a kid and I was just fine." Some individuals may also have the mistaken belief that all "natural" infections confer life-long immunity, whereas all vaccine-derived immunity is short-lived.
Vaccines have never been tested in a true "vaccinated versus unvaccinated" study; the vaccines in the current schedule have never been tested collectively.
Diseases declined on their own due to improved hygiene and sanitation; "vaccines didn't save us."
Vaccines "shed" (can be transmitted by vaccinated individuals to others); therefore, cases of vaccine-preventable diseases in the population are driven by the vaccinated, not the unvaccinated.

Adapted from [2, 10, 23]; see Supplemental Information for a list of comprehensive rebuttals.

in vaccines [12]. Another commonly feared "toxin," the ethyl mercury that is part of the preservative thimerosal, has been removed from most routine vaccinations since 2001 (and was never present in live vaccine formulations), despite no evidence of harm [13]. Still, many argue that children are purposely "poisoned" via vaccines because it benefits the bottom line of "Big Pharma" and the physicians pharmaceutical companies work with.

Other arguments stem from misinformation regarding the immune system and vaccine response, claiming vaccines "overwhelm" the immune system, and that natural immunity is better than immunity induced by vaccines. The latter argument misses the point of vaccination entirely, and the former ignores the fact that the body is seeded by thousands of species of microbes and is exposed to countless antigens from birth onward; the relatively few additional antigens introduced via vaccination are, relatively speaking, a drop in the bucket [14].

As a result of the spread and increased acceptance of these arguments, researchers have documented reduced trust in medical practitioners by parents and an increase in concerns about vaccines. Although only 19% of parents noted "concerns about vaccines" in a 2000 survey [15], by 2009, 50% of parents had concerns [16] (reviewed in [17]).

THE CAST OF CHARACTERS

Although many parents may repeat uncritically the information they receive from vaccine denial groups, these claims rarely originate with the parent de novo. As noted above, iterations of the same arguments against and fears about vaccines have been used for well over a century, and they are merely recycled and updated to better reflect the modern science landscape and language. These updated vaccine myths are then circulated by a variety of influential individuals and organizations (Table 2) and are read and repeated by parents and other media consumers. Collectively, this "influencer" group has undue sway over the media when it comes to vaccine information, becaue some media stories on vaccination strive for "balance" in reporting. Although this idea of "balance" is false [18]—far more physicians and scientists support vaccines than not—the same antivaccine individuals are interviewed for news pieces repeatedly, increasing their exposure and profile in the news media.

Many of these "influencers" rely on the internet to spread their message (together, the individuals and organizations included in Table 2 have more than 7 million Facebook followers, although some overlap in followers may be expected). Recent work has demonstrated that approximately 80% of individuals use the internet yearly to search for health information [19], and relatively few discuss these findings with a healthcare professional. Kata [10] notes that "common assertions found online included: that vaccines cause illness; that they are ineffective; that they are part of a medical/pharmaceutical/government conspiracy; and that mainstream medicine is incorrect or corrupt. Misinformation was widespread, in the form of inaccuracies or outright deception." Although the effect of online misinformation on vaccination attitudes and decision making has not been carefully quantified, parents have often listed concerns similar to those on antivaccine websites when asked by researchers why they did not vaccinate [20, 21], suggesting permeation into community groups from antivaccine books and internet sites or similar sources of misinformation. Furthermore, even short exposure to vaccine-critical internet sites has been shown to increase perceived risks of vaccinating and minimize the risks of vaccine-preventable diseases [22].

Although many of the individuals who spread vaccine misinformation are ordinary citizens, the sources of most antivaccine tropes are individuals or groups who benefit from the spread of such inaccuracies. Many of the primary antivaccine "thought leaders" have written books or produced movies that characterize vaccines as dangerous and unsafe (see Supplemental Information for examples of antivaccine books and sites). Others run groups dependent on donations from individuals who support their ideas. Still others rely on clicks, advertising revenue, and product sales from online sites where they share articles on the "dangers" of vaccines. A recent analysis

Table 2. Thought Influencers in the Antivaccine Movement

Category	Name	Description
The Doctors	Andrew Wakefield	Former British physician; lead author of 1998 study in *The Lancet* suggesting MMR vaccination led to autism [1], since retracted. Discredited after an investigation into the study demonstrated undisclosed conflicts of interest and unethical conduct; subsequently, Wakefield lost his medical license. He currently lives in United States and remains active promoting antivaccine ideas, including the 2016 documentary VAXXED (see Supplemental Information for books, movies, and web sites from antivaccine thought influencers). Active on social media via the VAXXED page (~67 000 followers on Facebook).
	Robert Sears	California physician, author of "The Vaccine Book". Formulated an "alternative" vaccine schedule that delays many vaccines from the CDC-recommended schedule; this schedule has been widely promoted by other antivaccine activists and is often cited by parents, and reinforces the idea that children receive "too many, too soon" (see Table 1). Active on social media (~65 000 followers on Facebook).
	Sherri Tenpenny	Private practice physician in Ohio, author of "Vaccines: The Risks, the Benefits, the Choices, a Resource Guide for Parents" and "Saying No to Vaccines: A Resource Guide for All Ages". Co-founder of the International Medical Council on Vaccination (http://www.vaccinationcouncil.org/), whose purpose is to "counter the messages asserted by pharmaceutical companies, the government and medical agencies that vaccines are safe, effective and harmless." Active on social media (~215 000 followers on Facebook).
	Toni Bark	Private practice physician at "The Center for Disease Prevention and Reversal" in Illinois; prior vice-president of the American Institute of Homeopathy. Featured in Oprah.com and the recent web series "The Truth about Vaccines." Active on social media (~6000 followers on Facebook).
	Susanne Humphries	Private practice physician in Maine and Virginia, author of "Dissolving Illusions: Disease, Vaccines and the Forgotten History". Active on social media (~31 000 followers on Facebook).
	Larry Palevsky	Private practice and holistic/integrative physician in New York. Featured in the web series "The Truth about Vaccines" and the anti-HPV vaccine documentary "The Greater Good". Active on social media (~13 000 followers on Facebook).
	Joseph Mercola	Former private practice physician in Illinois, runs the website and business Mercola.com. Author of "The Great Bird Flu Hoax: The Truth They Don't Want You to Know About the 'Next Big Pandemic'". Founder of "Health Liberty" ("A nonprofit coalition formed by Mercola.com, National Vaccine Information Center, Fluoride Action Network, Institute for Responsible Technology, Organic Consumers Association, and Consumers for Dental Choice, to help protect every American's freedom to make voluntary health choices"). Active on social media (~1 600 000 followers on Facebook).
The Celebrity	Jenny McCarthy	Actress and comedian, "Mommy warrior," Generation Rescue spokesperson, parent of autistic child. Author of "Louder Than Words: A Mother's Journey in Healing Autism"; "Mother Warriors: A Nation of Parents Healing Autism Against All Odds"; and "Healing and Preventing Autism: A Complete Guide". Active on social media (~1 100 000 followers on Facebook).
The Organizers	J. B. Handley	Activist and parent of autistic child, cofounder of Generation Rescue and cofounder and contributor to the Age of Autism blog. Both organizations suggest that vaccines are a major factor driving the development of autism. Active on social media (~25 000 followers on Facebook).
	Robert F. Kennedy, Jr.	Environmental lawyer, author of "Thimerosal: Let the Science Speak" and controversial 2005 article, "Deadly Immunity," published in Rolling Stone and Salon but later retracted. Reported in 2017 to have been appointed to lead a vaccine safety commission for President Trump. Active on social media (~20 000 followers on Facebook).
	Barbara Loe Fisher	Activist and founder of the National Vaccine Information Center (NVIC), originally Dissatisfied Parents Together (DPT). Fisher began speaking out against vaccines after her son suffered what she believes is a vaccine injury. Coauthor of "A Shot in the Dark" and "Vaccines, Autism & Chronic Inflammation: The New Epidemic". Via the NVIC, Fisher is active in tracking and responding to local and state vaccine-related legislation. Active on social media via the NVIC (~193 000 followers on Facebook).
The "Mommy Bloggers"	Sarah Pope	Nutrition and parenting blogger who has dubbed herself the "Healthy Home Economist." Appeared on the "Late Show with Jon Stewart" to defend her antivaccine stance. Active on social media (~155 000 followers on Facebook).
	Megan Heimer	Mother of 5, naturopath, and "wellness" blogger at "Living Whole." Heimer posts self-declared "common sense" information about healthy living, which includes avoiding vaccines. Active on social media (~26 000 followers on Facebook).
	Kate Tietje	Mother of 5, cooking and parenting blogger at "Modern Alternative Mama;" sells "health and wellness" products at Earthley.com. Active on social media (~70 000 followers on Facebook).
The Opportunists	Vani Hari	The "Food Babe;" influential "food safety" advocate who and social media star who has argued against vaccines. Hari recently had her first child and joined the ranks of the "mommy bloggers," recommending against vaccines. Instead of accepting the influenza vaccine during pregnancy, she recommended "wash hands often, reduce stress, exercise, drink lots of filtered water, eat fermented foods, and avoid industrial toxins". Active on social media (~1 200 000 followers on Facebook).
	Mike Adams	Owner/operator of "Natural News" website; has dubbed himself "The Health Ranger." Adams is a key purveyor of conspiracy theories, suggesting the government is lying to the public about vaccines, Ebola, influenza, and much more, simultaneously denying Zika exists and profiting from Zika mosquito repellent (https://www.healthrangerstore.com/collections/Health-Rangers-Bugs-Away-Spray-defense-against-the-Zika-Mosquitos). Active on social media (~2 200 000 followers on Facebook).

Abbreviations: CDC, Centers for Disease Control and Prevention; DPT, dissatisfied parents together; HPV, human papillomavirus; MMR vaccine, measles, mumps, and rubella.

of antivaccination websites demonstrated that every website examined except 1 "contained arguments against vaccination that could be considered disingenuous" [23], supporting their role in the dissemination of misinformation about vaccines. Furthermore, "mommy blogs" in particular have been analyzed and found to tell persuasive stories, suggesting that vaccines pose a threat to children, which may be circulated to large numbers of readers [24].

Although many of the antivaccine arguments that parents refer to may ultimately stem from or be promoted by such celebrities and/or websites, parents may not always believe or know their information has been filtered through these individuals, nor that they have been influenced by such. In addition, an individual's personal history of vaccination or medical care for themselves or their children may also color their view of vaccinations, independent of or reinforced by exposure to media on vaccines. There is wide heterogeneity in individuals who doubt vaccines [17, 25], so although understanding individuals and groups involved in antivaccine messaging is important, scientists should not assume that all individuals who express skepticism about vaccines share the same background, media consumption, or views.

It should also not be assumed that individuals who question vaccines have merely absorbed antivaccine messages (including those from the above sites and individuals) in a vacuum. Both vaccine hesitancy and vaccine promotion are influenced by the social and cultural contexts in which messages are received [26], as discussed below.

THE SPECTRUM OF VACCINE SKEPTICISM

There are many different subpopulations of individuals with divergent reasons for not vaccinating or delaying vaccines [27]. This may be due to a variety of factors, including (1) complacency (low-risk perceptions of vaccine-preventable diseases), (2) lack of convenient access to vaccine services, (3) or lack of confidence in vaccines due to concerns about safety and other vaccine issues [25, 28].

Although many may characterize all individuals who eschew vaccines as "anti-vaccine" or "vaccine deniers," in reality there is a broad spectrum of individuals who choose not to have themselves or their children vaccinated. These range from individuals who are solidly antivaccine, frequently termed "vaccine rejectors" (VRj), to those who may accept or even advocate for most vaccines but have concerns over 1 or more vaccines. Hagood and Mintzer Herlihy [29] suggest a 3-category model, characterizing individuals as VRj, vaccine-resistant (VR), or vaccine-hesitant (VH). Vaccine rejectors are those who are "unyieldingly entrenched in their refusal to consider vaccine information," prone to conspiracy theory thinking, and may eschew traditional medical providers altogether in favor of "complementary" or "alternative" medical practices and, as such, very unlikely to change their opinions on vaccines. The VR are those who may currently reject vaccination but are still willing to consider information, and they have a lower incidence of belief in conspiracy theories than VRj individuals. The VH individuals tend to have anxiety about vaccinations but are not committed to vaccine refusal [29]. These groups correspond roughly to the "refusers," "late/selective vaccinators," and "the hesitant" identified in [30]. Interventions targeted at changing minds or attitudes to increase vaccine acceptance need to take into consideration this spectrum of beliefs regarding vaccines to be properly tailored to the targeted audience [26, 31], rather than assuming that all individuals with vaccine concerns have a single cohesive belief system.

As the above demonstrates, there is no "one size fits all" model for responding to vaccine hesitancy or denial. In the experience of the author, most of the ideas scientists commonly have about vaccine rejection seem to fit in more with the VRj group. Although this group may be the most vocal about their vaccine concerns, it is likely that they are in the minority in the spectrum of individuals adverse to vaccines; Leask et al [30] suggest that less than 2% of all parents are outright refusers. However, these active rejectors may cause damage in the general public by amplifying myths and misinformation about vaccination and shift the opinions of others away from vaccine acceptance [32].

WHAT TO DO AND HOW TO RESPOND AS AN EXPERT LACKING PATIENT CONTACT

Most interventions in recent years have focused on the VH. Vaccine hesitancy has been defined as "delay in acceptance or refusal of vaccines despite availability of vaccination services" [25], to separate them from individuals or children who may be delayed on vaccines through lack of services or access rather than a philosophical belief. This group is generally thought to be the most amenable to interventions, because they typically are not solidly antivaccine and may be considered "fence-sitters" on many vaccine issues, who have not strongly committed to either a "pro" or "anti" vaccine stance. Some concerns these parents express over vaccines are seemingly minor, including pain during injections and fevers after vaccination [33], but they may also have concerns about autism and the MMR vaccine, Guillain-Barré syndrome and the influenza vaccine, or others [33].

Most articles examining interventions for the VH were written with healthcare providers as primary targets [30, 34, 35]. Although microbiologists and infectious disease experts may not always have direct patient care responsibilities, they likely have extensive knowledge of the concepts underlying vaccination and of the diseases that vaccines prevent. However, scientists do not always know the rhetorical tricks and tactics [10] that vaccine rejectors and their leaders (see Table 2) frequently use; engaging them can be a mistake without understanding not only the science, but also the objections and references that vaccine rejectors may use. Understanding the arguments and concerns that individuals have about vaccines, and from where they originate, can allow for better communication regarding vaccines on the part of scientists.

Furthermore, scientists should realize that engaging directly with active rejectors will be very unlikely to change minds, although less is known about the effectiveness of this tactic on "lurkers" or other readers or listeners who may be following along with a conversation but not participating. Prior research has documented that exposure to social information online can

impact attitudes and behavior [36], although this has not been tested explicitly with readers of vaccine information, either provaccine or antivaccine.

As noted previously, one impulse many scientists may have is to simply educate the public. Known as the "information deficit model" of science communication, this model assumes that the public is merely uneducated or undereducated about vaccines, and that providing additional factual information will fill this knowledge gap and lead people toward vaccinating [28]. Unfortunately, information alone has not been shown to increase vaccine confidence among hesitant parents [9, 37].

This is not to suggest that providing knowledge is unimportant. Filling in data gaps and acting as a reliable, factual source of information is an essential service to those genuinely seeking science-based evidence about vaccination. This information can be communicated in person with friends or family members (particularly those with shared values) [38, 39], submitted to local newspapers as opinion pieces or letters to editors [40], or provided online through blog posts, social media updates, or other sites on the internet, where it may be inadvertently "stumbled upon" by searches or references from other links. Individuals should be aware that such educational efforts are likely to backfire for individuals deeply entrenched in vaccine rejection [8] but have been cited in "conversion" stories of individuals who moved across the spectrum from vaccine doubter to advocate [41].

Furthermore, the frequent use of conspiracy theory thinking among antivaccine thought leaders engenders a lack of trust towards the medical and scientific communities. As such, providing more education to some on the spectrum of vaccine refusal/hesitancy will be ineffective [23], because it is unlikely to be sufficient to simply reassure many VH parents that expert groups have confirmed that vaccines are safe and effective when these parents already distrust the "experts" [23].

Still, biomedical scientists who are vocal in their support for vaccines can serve to cement the idea that vaccination is "normal" and expected. Kestenbaum and Feemster [34] note that a "…parent's motivation to vaccinate their children is also influenced by social norms, which are the rules that a group uses for appropriate and inappropriate values, beliefs, attitudes, and behaviors". A recent Pew survey found that 82% of US adults agree that "healthy children should be required to be vaccinated to attend school because of potential risk to others," and 88% agree that vaccine benefits outweigh the risks [42]. Although vaccine hesitancy does exist, vaccination on schedule is still the norm for the great majority of families. As a professional who accepts vaccines as a part of life for yourself and your children, conveying that information to your networks can help to subtly shift opinion on what Shelby and Ernst [43] call "the greatest story never told: the uneventful vaccination" (see Figure 1). Although stories of uncomplicated vaccine administration are less likely to "go viral" than stories of injured children [43, 44], these stories can further ingrain the idea that vaccines are being given every day without incident.

For those who want to get more deeply involved, Shelby and Ernst [43] put forward the idea of a "vaccine ambassador" program at physician offices. The authors noted that "There is a growing passion among parents who vaccinate to begin speaking up about the importance of immunization, and yet we continue to hear from these parents that they don't know how to help." They suggest that physicians put a call out to their patients, and willing parents could provide contact information that can be given to VH parents. The "ambassadors" would receive training and share the reasons why they decided to vaccinate their own children [43]. Particularly if this is done amongst individuals with shared values [26], such a program may be beneficial.

Ambassadors may benefit from using the C.A.S.E. method outlined by Singer [45], which includes steps to corroborate parents' fears, offer information about the educator and their personal experience with vaccines, provide information about the science regarding vaccines, and explain recommendations,

Figure 1. Examples of photos posted to the author's social media accounts. (A) The author (middle) and her older children after receipt of seasonal influenza vaccines. (B) The author's youngest child at Walt Disney World, wearing a shirt saying "Fully Vaccinated. You're Welcome." Both techniques can serve as conversation-starters around vaccination.

all within a context of empathy and an established relationship [29, 45]. A recent publication by Schoeppe et al [46] involved parents as immunization advocates to address vaccine hesitancy in Washington state, whose school entry exemption rate was 3 times the national average. Although lacking a control group, they found that vaccine hesitancy was reduced in their population, from 23% to 14%, and the number of parents who agreed vaccination is a good idea rose. Scientists may adapt recommendations from papers targeting healthcare professionals to work with such groups [30, 35].

Although many scientists may hesitate to "get political," vaccine policy is set at the state level; as such, privately contacting state legislators and advocating for the strengthening of vaccine exemption policies is another way to protect herd immunity, because states with stricter exemption criteria have higher rates of vaccination compliance [47]. California recently passed SB277, which eliminated religious and philosophical exemption for school admittance. In their first year of data analysis, they found that vaccination rates rose in students attending kindergarten 2.8 percentage points [48]. Similarly in Michigan, state officials issued a regulation requiring consultation with local health departments before obtaining a vaccine waiver, resulting in 35% fewer vaccine exemptions in the first year [49]. In each case, an outbreak may have helped both to sway legislators and mobilize parents (the Disneyland measles outbreak in California, and a large outbreak of pertussis associated with a Traverse City charter school in Michigan), but one need not wait for an emergency situation to push state legislators to strengthen vaccine regulations. This is one way scientists can work "behind the scenes," to advocate for and promote such legislation.

Academics can also examine vaccine policies at their own institutions. My current institution requires only the MMR for admission, whereas many universities have more rigorous vaccine requirements. The University of California system will expand their vaccine requirements as of fall 2017, requiring students be vaccinated for hepatitis B, measles, mumps and rubella, chicken pox, meningococcus, and tetanus, diphtheria and whooping cough before registration. Advocating for vaccine protection for college students is another way scientists can use their expertise to increase vaccination rates and demonstrate the importance of immunization.

CONCLUSIONS

Finally, although there may be no single leader of an antivaccine "movement," many of those listed in Table 2 are highly media-savvy and unafraid to push their opinions that vaccines are dangerous, full stop. Scientists, by our training and often by our nature, are often loathe to think of issues without bringing in shades of gray, whereas vaccine thought leaders frequently express strict black-and-white thinking. Advocating for vaccines is not always easy; it may necessitate leaving one's comfort zone, and open one up as a target of harassment [50]. However, with so much at stake, shouldn't subject experts be on the forefront of this fight?

Supplementary Data

Supplementary materials are available at *Open Forum Infectious Diseases* online. Consisting of data provided by the authors to benefit the reader, the posted materials are not copyedited and are the sole responsibility of the authors, so questions or comments should be addressed to the corresponding author.

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References

1. Poland GA, Jacobson RM. The age-old struggle against the antivaccinationists. N Engl J Med **2011**; 364:97–9.
2. Hausman BL, Ghebremichael M, Hayek P, Mack E. 'Poisonous, filthy, loathsome, damnable stuff': the rhetorical ecology of vaccination concern. Yale J Biol Med **2014**; 87:403–16.
3. Omer SB, Richards JL, Ward M, Bednarczyk RA. Vaccination policies and rates of exemption from immunization, 2005–2011. N Engl J Med **2012**; 367:1170–1.
4. Omer SB, Salmon DA, Orenstein WA, et al. Vaccine refusal, mandatory immunization, and the risks of vaccine-preventable diseases. N Engl J Med **2009**; 360:1981–8.
5. Phadke VK, Bednarczyk RA, Salmon DA, Omer SB. Association between vaccine refusal and vaccine-preventable diseases in the united states: a review of measles and pertussis. JAMA **2016**; 315:1149–58.
6. Centers for Disease Control and Prevention. Measles cases in the United States reach 20-year high. Available at: https://www.cdc.gov/media/releases/2014/p0529-measles.html. Accessed August 2, 2017.
7. Mitra T, Counts S, Pennebaker JW. Understanding anti-vaccination attitudes in social media. Proceedings of the Tenth International Association for the Advancement of Artificial Intelligence (AAAI) Conference on Web and Social Media (ICWSM 2016) (pp. 269–278). **2016**. Available at: https://www.aaai.org/ocs/index.php/ICWSM/ICWSM16/paper/view/13073/12747. Accessed August 2, 2017.
8. Nyhan B, Reifler J, Richey S, Freed GL. Effective messages in vaccine promotion: a randomized trial. Pediatrics **2014**; 133:e835–42.
9. Jarrett C, Wilson R, O'Leary M, et al. Strategies for addressing vaccine hesitancy - a systematic review. Vaccine **2015**; 33:4180–90.
10. Kata A. Anti-vaccine activists, Web 2.0, and the postmodern paradigm–an overview of tactics and tropes used online by the anti-vaccination movement. Vaccine **2012**; 30:3778–89.
11. Daly G. Vacctivism terminology: how to empower instead of cower. Available at: https://issuu.com/naturalmothermagazine/docs/febraury_2017_final. Accessed August 2, 2017.
12. Offit PA, Jew RK. Addressing parents' concerns: do vaccines contain harmful preservatives, adjuvants, additives, or residuals? Pediatrics **2003**; 112:1394–7.
13. Offit PA. Thimerosal and vaccines–a cautionary tale. N Engl J Med **2007**; 357:1278–9.
14. Offit PA, Quarles J, Gerber MA, et al. Addressing parents' concerns: do multiple vaccines overwhelm or weaken the infant's immune system? Pediatrics **2002**; 109:124–9.
15. Gellin BG, Maibach EW, Marcuse EK. Do parents understand immunizations? A national telephone survey. Pediatrics **2000**; 106:1097–102.
16. Freed GL, Clark SJ, Butchart AT, et al. Parental vaccine safety concerns in 2009. Pediatrics **2010**; 125:654–9.
17. Gowda C, Dempsey AF. The rise (and fall?) of parental vaccine hesitancy. Hum Vaccin Immunother **2013**; 9:1755–62.
18. Voices for Vaccines. Avoiding False Balance: Vaccines in the Media Available at: https://www.voicesforvaccines.org/content/uploads/2015/02/False-Balance-Toolkit-VFV.pdf. Accessed August 2, 2017.
19. Pew Research Center. Health Online 2013. Available at: http://pewinternet.org/Reports/2013/Health-online.aspx. Accessed August 2, 2017.
20. Salmon DA, Moulton LH, Omer SB, et al. Factors associated with refusal of childhood vaccines among parents of school-aged children: a case-control study. Arch Pediatr Adolesc Med **2005**; 159:470–6.
21. Salmon DA, Sotir MJ, Pan WK, et al. Parental vaccine refusal in Wisconsin: a case-control study. WMJ **2009**; 108:17–23.

22. Betsch C, Renkewitz F, Betsch T, Ulshöfer C. The influence of vaccine-critical websites on perceiving vaccination risks. J Health Psychol **2010**; 15:446–55.
23. Kata A. A postmodern Pandora's box: anti-vaccination misinformation on the Internet. Vaccine **2010**; 28:1709–16.
24. Tangherlini TR, Roychowdhury V, Glenn B, et al. "Mommy blogs" and the vaccination exemption narrative: results from a machine-learning approach for story aggregation on parenting social media sites. JMIR Public Health Surveill **2016**; 2:e166.
25. MacDonald NE. Vaccine hesitancy: definition, scope and determinants. Vaccine **2015**; 33:4161–4.
26. Attwell K, Freeman M. I immunise: an evaluation of a values-based campaign to change attitudes and beliefs. Vaccine **2015**; 33:6235–40.
27. Dubé È, MacDonald NE. Managing the risks of vaccine hesitancy and refusals. Lancet Infect Dis **2016**; 16:518–9.
28. Rossen I, Hurlstone MJ, Lawrence C. Going with the grain of cognition: applying insights from psychology to build support for childhood vaccination. Front Psychol **2016**; 7:1483.
29. Hagood EA, Mintzer Herlihy S. Addressing heterogeneous parental concerns about vaccination with a multiple-source model: a parent and educator perspective. Hum Vaccin Immunother **2013**; 9:1790–4.
30. Leask J, Kinnersley P, Jackson C, et al. Communicating with parents about vaccination: a framework for health professionals. BMC Pediatr **2012**; 12:154.
31. Butler R, MacDonald NE. Diagnosing the determinants of vaccine hesitancy in specific subgroups: The Guide to Tailoring Immunization Programmes (TIP). Vaccine **2015**; 33:4176–9.
32. Schmid P, MacDonald NE, Habersaat K, Butler R. Commentary to: How to respond to vocal vaccine deniers in public. Vaccine **2016**: doi: 10.1016/j.vaccine.2016.09.065.
33. Kennedy A, Basket M, Sheedy K. Vaccine attitudes, concerns, and information sources reported by parents of young children: results from the 2009 HealthStyles survey. Pediatrics **2011**;127 (Suppl 1):S92–9.
34. Kestenbaum LA, Feemster KA. Identifying and addressing vaccine hesitancy. Pediatr Ann **2015**; 44:e71–5.
35. Loehr J, Savoy M. Strategies for addressing and overcoming vaccine hesitancy. Am Fam Physician **2016**; 94:94–6.
36. Hsueh M, Yogeeswaran K, Malinen S. "Leave Your Comment Below": can biased online comments influence our own prejudicial attitudes and behaviors? Hum Commun Res **2015**; 41:557–76.
37. Sadaf A, Richards JL, Glanz J, et al. A systematic review of interventions for reducing parental vaccine refusal and vaccine hesitancy. Vaccine **2013**; 31:4293–304.
38. Witteman HO. Addressing vaccine hesitancy with values. Pediatrics **2015**; 136:215–7.
39. McRoberts C. The Most Important Playground Conversation: How to Persuade a Friend to Vaccinate. Available at: https://violentmetaphors.com/2013/12/20/the-most-important-playground-conversation-how-to-persuade-a-friend-to-vaccinate/. Accessed August 2, 2017.
40. Shelby A. Voices for Vaccines: Writing an Op-Ed for Publication. Available at: https://www.voicesforvaccines.org/content/uploads/2013/01/OpEdtoolkit.pdf. Accessed August 2, 2017.
41. Krolak B. I Used to Be Anti-Vaccine. Available at: https://www.voicesforvaccines.org/1769-2/. Accessed August 2, 2017.
42. Funk C, Kennedy B, Hefferon M. Vast majority of Americans say benefits of childhood vaccines outweigh risks: Pew Research Center **2017**. Available at: http://www.pewinternet.org/2017/02/02/vast-majority-of-americans-say-benefits-of-childhood-vaccines-outweigh-risks/. Accessed August 2, 2017.
43. Shelby A, Ernst K. Story and science: how providers and parents can utilize storytelling to combat anti-vaccine misinformation. Hum Vaccin Immunother **2013**; 9:1795–801.
44. McGrath K. Vaccine Injury Stories: the Sacred Cows of the Internet? Available at: https://www.voicesforvaccines.org/vaccine-injury-stories-the-sacred-cows-of-the-internet/. Accessed August 2, 2017.
45. Singer A. Communicating Vaccine Safety Information to Parents: A New Framework. Available at: https://cdc.confex.com/cdc/nic2010/webprogram/Paper22643.html. Accessed August 2, 2017.
46. Schoeppe J, Cheadle A, Melton M, et al. The immunity community. Health Promot Pract **2017**: doi: 10.1177/1524839917697303.
47. Blank NR, Caplan AL, Constable C. Exempting schoolchildren from immunizations: states with few barriers had highest rates of nonmedical exemptions. Health Aff **2013**; 32:1282–90.
48. 2016–2017 Kindergarten Immunization Assessment – Executive Summary California Department of Public Health, Immunization Branch, **2017**. Available at: https://archive.cdph.ca.gov/programs/immunize/Documents/2016-17_CA_KindergartenSummaryReport.pdf.
49. Gugliotta G. Refined Vaccine Waivers Improve Vaccination Rate in Michigan, **2017**. Available at: http://www.medscape.com/viewarticle/878615. Accessed August 2, 2017.
50. Hughes V. Mercury rising. Nat Med **2007**; 13:896–7.