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Utilizing health information technology to improve vaccine communication and coverage

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Vaccination coverage is still below the Healthy People 2010 and 2020 goals. Technology use in the US is widespread by patients and providers including text message, email, internet, social media and electronic health records. Health information technology (IT) interventions can facilitate the rapid or real-time identification of children in need of vaccination and provide the foundation for vaccine-oriented parental communication or clinical alerts in a flexible and tailored manner. There has been a small but burgeoning field of work integrating IT into vaccination interventions including reminder/recall using non-traditional methods, clinical decision support for providers in the electronic health record, use of technology to affect workflow and the use of social media. The aim of this review is to introduce and present current data regarding the effectiveness of a range of technology tools to promote vaccination, describe gaps in the literature and offer insights into future directions for research and intervention.

Introduction

Technology, ever present in society, offers new and emerging methods to improve vaccination coverage. Because of its prevalence and flexibility, technology provides promising tools to address vaccination barriers for families, health care providers and the broader community. This review documents levels and types of technology use in the general US population, as well as current vaccination coverage; it explores common barriers to vaccination and describes how technology has been increasingly implemented to overcome these hurdles. The aim of this review is to introduce and present current data regarding the effectiveness of a range of technology tools to promote vaccination, describe gaps in the literature and offer insights into future directions for research and intervention.

Technology Use in the United States

Technology use in the US is widespread. Most (87%) adults in the US have a cell phone and that rate may be higher in low-income populations.[1] In fact, the current wireless penetration is 102% of the US population, signifying that there are more cell phones than people.[2] It is also estimated that 35.8% of households are currently wireless-only and no longer have a landline.[2] Leveraging the use of these cell phones, text messaging has become ubiquitous. More than 70% of all cell phone owners and 90% of those 18–29 y of age, the age of many new parents, send text messages.[3] The intensity of text messaging among these younger adults is also particularly high, with those 18–29 y olds sending and receiving a mean of nearly 90 texts per day. These patterns of text message use create an ideal platform for targeted, health-related communication.

The growth of cellular phone use and texting is paralleled by the widespread use of the internet, social media and email. According to data from the Pew Internet and American Life Project, 75% of adults and 95% of adolescents now have internet access. Two-thirds of online adults and 89% of online young adults use social media to connect with others.[4,5] Email also remains popular. Most (92%) adult internet users use email with 61% accessing email on a typical day.[5] This prevalent use of email, internet and social media creates other promising routes for health communication.

In addition to consumer's use of technology, healthcare providers are being incentivized to integrate technology into their practice. The Health Information Technology for Economic and Clinical Health (HITECH) Act, part of the American Reinvestment and Recovery Act of 2009, included monetary incentives tied to "meaningful" use of electronic health records (EHRs).

At least partially as a result, the number of healthcare providers using EHRs is increasing. According to the 2011 Physician Workflow study, 54% of physicians had adopted an EHR system, with 76% reporting that their system met these federal "meaningful use" criteria.[6] The number of adopters among primary care providers was slightly higher at 58%. In the 2012 National Ambulatory Medical Care Survey (NAMCS), 72% of office-based physicians had adopted an EHR system.[7] However, there is some evidence that pediatric adoption of EHRs use lags behind general adoption in medicine.[8] Of note, the public has also demonstrated a small but increasing interest in the use of personal electronic health records to manage their own and their families' health.[9-11]

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The presence of EHR use and the resulting ability to have vaccination data in electronic form provides an important foundation for delivering information technology (IT) based vaccine interventions. The capture of vaccine data in electronic form is also supported by a growing number of immunization information systems (IIS) or immunization registries. An IIS is a population-based system that collects and centralizes vaccination data for children and adolescents from vaccination providers at a regional or state level, integrating vaccination administration for any given child across all the sources where they may receive vaccination. As of 2011, 50 states, five cities and the District of Columbia all had an IIS.[12] This centralization is especially important for populations, such as those with low-income, that may be more mobile or see multiple providers, leading to fragmented vaccination records.[13-16] In addition to collecting vaccination information, some IIS such as New York City's Citywide Immunization Registry (CIR) have mechanisms in place to provide vaccination information back to the clinician's EHR, allowing more complete vaccination information to be available at the point of care. Since vaccination-specific criteria related to communicating with an IIS are included in the first two stages of EHR meaningful use incentives, and are currently under consideration for the third,[17] this transfer of vaccination information between these systems and EHRs should only increase over time.[18]

Current Vaccination Coverage

This widespread of use of technology provides an ideal platform to help in the delivery of vaccines, one of the most important public-health interventions.[19] Despite great strides in improving vaccination coverage in children, according to the latest National Immunization Survey, only 68.5% of young children 19–35 months old have completed their primary immunization series, which includes vaccination against diphtheria, polio, measles, hepatitis B, hemophilus influenza B, varicella and pneumococcal disease.[20] This falls short of the Healthy People 2010 and 2020 goals of 80% coverage,[21] and leaves nearly one third of US children incompletely protected against these vaccine-preventable diseases. Coverage for the more recently introduced adolescent immunization schedule has surpassed that of young children for vaccination against pertussis (tetanus-diphtheria-acellular pertussis [Tdap] [78.2% coverage]), and against meningococcal disease (70.5%). However, much more limited success has been seen with vaccination against human papilloma virus new (HPV).[22] In the latest National Immunization Survey-Teen only half (53%) of female adolescents 13–17 y old initiated the series and only 34.8% received the 3 doses needed for full protection. Finally, for seasonal vaccinations such as influenza, national coverage remains low with only 49.4% of children and adolescents over 6 mo of age receiving the vaccine by the end of March in the 2011–12 season.[23] At the same time, the United States has experienced a re-emergence of many vaccine preventable diseases including pertussis, haemophilus influenza Type B and measles; some associated with low vaccination coverage.[24-26] Influenza remains a persistent threat as evidenced by the 2009 H1N1 pandemic as well as seasonal influenza outbreaks, including the recent 2012–13 epidemic. Disparities also still exist in vaccination coverage that need to be addressed. For example, young children living in poverty have lower completion rates for their primary vaccination series[20] and Latina and African-American adolescent girls have poorer completion rates for the HPV vaccine.[22]

Factors Affecting Vaccination: Natural Targets for Technology-Based Interventions

Many factors that lead to undervaccination at the parent, provider, system and community level could potentially be addressed by technology. In order for a child to be vaccinated, the family needs to know that their child is at risk for a vaccine-preventable disease, that their child is need of the vaccination, to believe that the vaccine is safe and effective, to know where to go to be vaccinated, and to remember to come in for the vaccination. When families visit a health care provider, the provider needs to take advantage of the opportunity for vaccination as well as feel they are able to adequately provide information regarding the vaccine to answer questions and address concerns.[27,28] On a systems level, processes including workflows and vaccine supply chains need to be effectively and consistently implemented. Finally, community support for vaccination may be helpful to provide evidence-based, positive-vaccine messages.

Clinicians and families have varied vaccine informational needs, making the flexibility of Health IT approaches particularly beneficial. For example, information needs of parents making vaccine decisions about a new vaccine, such as when the varicella vaccine was added to the routine vaccination schedule in 1996,[29] may differ from those for a vaccine that has been licensed for a number of years. Vaccine changes, such as moving from 7-valent to 13-valent pneumococcal conjugate vaccine, also require distinct messages.[30] Even within the same vaccine, information needs may differ. For example, influenza vaccination notifications may need to be tailored for those at particularly high risk for influenza morbidity, such as children with asthma, vs. other groups.[31]

The rapidly evolving, lengthy, and heavily footnoted schedule can also pose a barrier to health care providers. For example, over a relatively short period of time, influenza vaccination recommendations evolved from specific groups to universal coverage,[32,33] which in the transition years could have led to confusion. Similarly, providers who are focused on providing adolescent vaccinations just at the 11–12 y visit may have more difficulty remembering to provide an additional dose of the meningitis vaccine for adolescents at 15 y since that booster dose was more recently introduced. Providers may also be at risk of missing opportunities to vaccinate children with medical conditions that require targeted vaccination beyond the ones recommended for the general population such as the pneumococcal polysaccharide vaccine. On a system level, tracking and documenting the large number of vaccines that are routinely provided at an individual visit can be overwhelming. Using a Health IT approach, much of the adaptation needed for each of these scenarios can occur "behind-the-scenes" by a software system rather than through more costly and time-intensive human effort.

Certain populations at high risk for undervaccination may also need specific consideration when designing interventions. For example, families with low health literacy have been shown to have distinct vaccine education needs.[34-38] Meeting the needs of this group is particularly important since 90 million Americans have low health literacy[39] with minority and low-income populations at greatest risk.[40] Vaccine interventions in this group ideally should avoid or simplify written materials, two objectives facilitated through the use of health information technology. Additionally, use of IT interventions may be particularly helpful for populations at risk for undervaccination for whom traditional methods have not been effective. For example, although reminder/recall are widely recommended and utilized, they have been less successful in low-income and adolescent populations than using traditional methods such as paper mailing or phone reminders, often due to changing contact information.[41-45] Interestingly, research has demonstrated that those who use smart phones rather than computers to access the internet are more likely to interact with technology as opposed to simply consuming information; this interaction may increase the impact of interventions.[46] Traditionally underserved groups such as African Americans and Latinos are especially likely to access the internet through smart phones.[47] Therefore they may potentially benefit most from health interventions that use the internet and social media in an interactive fashion.

Technology-Based Interventions to Improve Vaccination

IT in health care has already begun to demonstrate great potential to transform how vaccine delivery is supported and to substantially improve vaccination coverage in the United States. Using immunization data in electronic form, it facilitates the rapid or real-time identification of children in need of vaccination on a much larger scale than individual chart review, and then provides the foundation for vaccine-oriented parental communication or clinical alerts in a flexible and tailored manner. There has been a small but burgeoning field of work integrating IT into vaccination interventions targeting the family or individual child, the health care provider, system or the community. These include reminder/recall using non-traditional methods, clinical decision support for providers in the electronic health record, use of technology to affect work-flow, and the use of social media.

Parent-focused interventions: Reminder/recall interventions: Interactive voice response, text message and email. One of the most commonly utilized interventions for communicating with families about vaccinations is the use of reminder/recall. Reminder/recall interventions notify parents that their child will soon need a vaccination or recall them for overdue vaccinations. They are widely recommended by the US Task Force on Community Preventive Services[28] as well as numerous organizations including the American Academy of Pediatrics, Society for Adolescent Health and Medicine and the National Vaccine Advisory Committee.[48-50] Traditionally, reminder/recall interventions use mail or telephone.

Substantially extending the capabilities of typical phone reminders, interactive voice response (IVR) systems allow for phone conversations between the family at home and a computer-generated human voice. Families at home respond to the system with their keypad or by speaking, and clinicians may be alerted for concerning responses. The system can be programmed to tailor conversations to the needs of particular families and to provide a program of phone calls addressing a range of health issues over time. However, although this technology has begun to be explored in obesity and asthma,[51-53] IVR has not been widely implemented in order to promote vaccination.

Two newer reminder/recall methods are the use of text messages and email. These approaches seek to address the problem that traditional reminder/recall have been less effective in low-income and adolescent populations, for whom vaccine disparities may exist.[41-45] An important aspect of these novel forms of reminder/recall is the scalability and ability to reach large populations at little additional cost. Text messages costs only a few cents or less and email is often free. The use of traditional methods on a large scale can also be personnel intensive in the case of letters and telephone calls. While autodialers allow scalability,[54,55] they may be seen as impersonal. With immunization and patient data already in an electronic form in electronic health records or IIS, technology-driven reminders including texts and email messages become easy to send. Such approaches are also becoming more widely available. Some electronic health records now offer text message reminders,[56] and vendors that have offered more traditional forms of reminder/recall now offer text messaging and email.[57]

Text messages. There are a number of reasons text messages potentially make effective vaccination reminders. Parents have reported that they attract their attention in a different way than a letter reminder.[58] They also reach the intended participant as opposed to a letter, which anyone in the household might open, or an automated telephone reminder, which will play for whomever answers the phone or picks up the answering machine message. Text messages also remain on a person's cellular phone, which is often with them, allowing potentially important reference information, such as influenza vaccine walk-in hours at a clinic, to be easily accessible. They also allow messages to be tailored based on factors such as age group, gender or chronic medical condition. This tailoring of information is important since different groups need different vaccines and even those requiring the same vaccine may have different vaccination needs; for example, some young children need two doses of influenza vaccine in a given season while others need just one.[59]

There are some potential limitations to text messages. First is their restriction to not more than 160 characters (less for some carriers) constraining the amount of information that can be included. However, the character limit forces the messages to be simple and brief which is useful in a population with low literacy or health literacy. Changes in contact information are another potential obstacle to successfully using text messages. While for low-income and adolescent populations the stability of traditional forms of contact information has been problematic,[41,43] at least in the short term, cellular telephone numbers appear to

be a more stable than home addresses or telephone numbers.[60] This instability of traditional forms of contact information may affect other populations as well; a recent reminder/recall study using letter reminders conducted in a pediatric, primarily rural or frontier, population in Montana using their state immunization information system was unsuccessful, thought perhaps to be in part due to unsuccessful delivery of letters.[61] Finally, cost has been raised as an issue, but many families, especially those with low-income, have unlimited text messages, perhaps mitigating the impact of cost on the success of these interventions.[57,58,60,62] The effects of costs particularly from the perspective of health care systems have not been studied, but vendors that have used traditional methods for reminder/recall now also offer text message reminders, so practices that already employ reminder-recall may incur similar costs.[57,62]

Although text messaging has been used sparsely for non-vaccination-related interventions in the pediatric and adolescent population, use has generally proven effective. Recent review of these interventions found significant effects of text messaging in 71% of the studies.[63] Their success in the adult population for non-vaccination related interventions has been mixed. They have been successfully used to promote medication adherence for contraception as well as HIV and smoking cessation treatment, but have been more limited in their effects on changing other health behaviors or improving self-management of chronic diseases.[64] However, the one field where text messaging so far has been successful in both pediatric and adult populations is vaccination reminder/recall.

The first iteration of text messages were conventional text message reminder/recall that, like traditional phone reminders, notified a patient for their family that their child was in need of vaccination. We successfully employed the use of these conventional text message reminder/recall to improve receipt of adolescent vaccinations including return for subsequent HPV vaccine doses,[65] as well as receipt of vaccination against meningitis and pertussis.[66] They have also been successfully used in an adult travel clinic to promote return for needed hepatitis doses,[67] as well as for receipt of the primary childhood vaccination series, although the sample size in that pilot study was too small to achieve statistical significance despite large differences between groups.[68]

While acting as a notification, these conventional text message reminders do not address other vaccine education needs. Although space is limited, text messages can also provide educational information to families that may help them make the decision to bring their child or adolescent in for vaccination. These may be particularly important in populations with low vaccine health literacy who may be at particular risk of undervaccination. In a large randomized controlled trial of over 9,000 low-income, urban children, we demonstrated the effectiveness of embedding health literacy promoting information into influenza vaccine text message reminders notifying families of special Saturday influenza vaccine clinics.[69] These were based on the most common factors affecting vaccination decisions reported by parents in previous studies. While the differences seen in these text message reminders were modest, they are in line with what has been noted in other reminder/recall studies. Further, these findings are important because the intervention was directed on a large scale at a low-income, minority population at high risk for incomplete vaccination; for vaccinations like influenza that must be delivered to large populations, small differences can have a large public health impact.[70]

Parents appear to be interested in text message reminders. In focus groups of parents of adolescents, we found that many of them preferred them to mail or phone reminders.[58] In a study of low-income parents in Kansas, 90% of those surveyed were open to text messages from their doctor or nurse;[71] we found similar rates in a group of low-income families in New York City.[62] In a national study, 56% of the 1612 parents surveyed were willing to register their cell number with their child's usual vaccination provider, and another 18% were undecided.[60] Parents prefer text messages that are simple, short and personalized and include provider information[58,62,72] Although to date text message interventions have focused on parents, as older adolescents play a role in vaccine decision-making, they can also be recipients of vaccine reminders.[73] Provider interest in text messaging has been mixed. In one study of providers in Kansas, 27% were willing and 43% undecided about using text-messaging,[74] although none had ever used text message reminders. It is likely that those who are unfamiliar with a technology may be less open, at first, to its use; few people are early adopters of new technology and most often wait and adopt when the majority adopts.[75] We found a much greater level of support (88%) in health care providers at practices where we have conducted text message reminder/recall interventions.[62] Government groups have also begun exploring the potential of text messaging. These efforts include health alerts from the United States Centers for Disease Control and Prevention (CDC),[76] as well as the text messaging service for pregnant women and new parents, Text4Baby, which is a partnership with the Department of Health and Human Services (HHS) and private companies. As of February 2013, over 215,000 pregnant women and over 285,000 parents of young children have subscribed.[77] This alone belies the national interest in use of text messaging for health education, at least in that population.

Email. The use of email as a reminder has many of the potential benefits of text messaging including scalability, low-cost and the ability to automatically tailor messages to specific patient populations as well as to ensure that the message reach the intended person. They are also a stable form of contact.[60] Unlike text messaging, email does not have a character count limit, supporting the delivery of more detailed information. Links to outside content can also be embedded. The prevalence of email use as well as the existence of policies from professional organizations to guide use of this tool provide a foundation for using email to improve health.[78] Outside of vaccination, the literature on email reminders or the use of email as a more general health communication tool is sparse. Data have been primarily focused on adults, and available adult data have been inconclusive or did not show evidence of a significant effect.[79-81] There are ongoing studies of email vaccine reminders, but they have not been published to date. In one national study, some parents, especially those with higher household incomes and those who were older, were interested in e-mail vaccine reminders.[60] More studies

on the use of email reminders for the pediatric and adolescent population are needed, particularly efforts focused on fostering vaccination. To facilitate such efforts some vendors now also offer email reminders.[57]

Provider-Focused Intervention: Clinical Decision Support

As with family-directed approaches, the use of health information technology has also proven effective in supporting provider-based vaccine interventions. Interventions for providers primarily focus on recommending vaccines, consistently, at all possible opportunities.[28] Missed opportunities for vaccination occur when children come to the medical home for visits but do not receive any or all due vaccines; while these are a universal problem, they disproportionally result in vaccination delay among children with Medicaid insurance.[82] Despite a common belief that missed opportunities arise because of vaccine contraindications, research has demonstrated that contraindications account for only a small proportion of missed opportunities.[83] Most missed opportunities occur at acute-care visits when a provider may not be thinking about vaccination or be aware a patient was undervaccinated. Parents have expressed willingness to accept vaccination during these visits.[84-86] As a result, strategies to increase vaccination at acute-care visits are a key component of initiatives to improve vaccination rates and, consequently, an important target for health information technology-based systems to improve care. Such interventions can also be used at any type of visit to target provider reluctance to recommend vaccines, especially in the case of adolescent vaccines like HPV.[87,88] They can also be useful for vaccines such as influenza that generate parental concern.[89]

Among the most effective provider-oriented alerts has been the use of clinical decision support (CDS) delivered through the EHR. In broad terms, CDS provides clinicians with clinical knowledge and patient-related information, intelligently filtered or presented at appropriate times, to impact clinical decision-making to enhance patient care.[90] Effective CDS depends upon having well-defined rules to guide recommendations; therefore, vaccination, which draws from rules published annually by the CDC that are widely disseminated, endorsed and accepted, are an ideal target for CDS. Studies have demonstrated the effectiveness of such rule-based algorithms in delivering accurate vaccine recommendations.[91] In addition, the capture of vaccination events as discrete data within EHRs, as prioritized by the American Academy of Pediatrics,[92] along with the aforementioned ability to integrate data from an IIS into the vaccine record, potentiate these interventions.

When vaccine CDS is implemented, alerts generally appear on-screen and summarize vaccines that are due to be given for a particular infant, child or adolescent. Such alerts have become increasingly standard within EHRs and may be designed to notify each member of the clinical team that vaccines are due. This approach helps to maximize the likelihood that the clinical team will approach families and offer vaccines as a standard part of each office visit, not just at well-child visits, which can help avoid missed opportunities.[85] Best practices for CDS implementation, based on systematic literature reviews, specify that these alerts are most effective when they automatically provide recommendations ("DTaP, IPV, Hib, PCV13, rotavirus vaccines needed") instead of just assessments ("this child is delayed") and deliver information at the time and location of decision making.[93,94] These reviews also demonstrate that computer-based is more effective than paper-based decision support. A limitation of these CDS interventions, especially for older children with less frequent visits, is that CDS only has the potential to improve care for those who come to the office. Pairing family or community-focused interventions that increase demand with office-based CDS may ultimately prove most effective in improving vaccination rates.[95,96]

Vaccine decision support has proven effective in reducing missed opportunities and improving vaccination rates. Work in this area builds upon a substantial literature on CDS that addresses such varied problems as reducing errors in medication ordering[97,98] as well as improving the reliability of a wide range of health care processes.[99] A systematic review of the effects of trials of on-screen, point of care computer reminders on processes and outcomes of care demonstrated a median improvement of nearly 4% in the ordering of recommended vaccines in diverse practice settings including adults and children.[100] We found in 3,000 young children that the implementation of vaccine alerts that appeared for nurses and physicians at four urban, primary care practices decreased missed opportunities at well visits and sick visits, and led to significant and substantial increases both in vaccination coverage as well as timeliness of vaccination.[101] We also explored the impact of these alerts on influenza vaccination rates among 12,000 older children with asthma cared for at urban and suburban practices.[102] While missed opportunities decreased and vaccination coverage increased overall, results were only statistically significant within urban practices.[103] Importantly, such practices often serve a population with higher rates of persistent asthma who are also at higher risk for influenza complications.

Related to alerts in the EHR for providers, EHR-linked personal health records (PHRs) provide a platform for delivering vaccine prompts to families to motivate vaccine receipt. Although PHR use is currently limited, a recent study illustrated that parents are willing to use a PHR to help manage their children's healthcare.[104] Suggesting that they might aid in promoting vaccination, one study in adults showed that those who used a PHR were more likely to receive an influenza vaccine.[105] Linking PHRs to smartphone use through an "app" is another emerging technology that warrants investigation.

System: Using Technology to Improve Vaccine Workflows and Documentation

System level factors affecting vaccination can also be targeted using technology. The use of EHR-based provider order entry facilitates workflow by transmitting clear orders and automatically documenting vaccine receipt. This is particularly important since in pediatric and adolescent medicine multiple vaccine doses are routinely given in one visit. The CDC, with the support of the American Academy of Pediatrics and others, is currently piloting the use of 2D bar codes to transfer vaccine information into an

EHR to avoid the time-consuming and potentially error-prone process of typing in manufacturer, lot and expiration data.[106,107] Such bar code systems could also potentially be used to track vaccine stock with alerts as to when more vaccine should be ordered, which could help support consistent vaccine supply. Finally, many IIS use online systems to support electronic transfer of vaccination information to meet reporting requirements as well as to order free Vaccines-for-Children (VFC) vaccine.

Addressing Vaccines in the Community: Internet, Web 2.0, and Social Media

Community-wide interventions such as public health campaigns have also been employed to raise awareness regarding the importance of vaccination.[27] Here too, technology, particularly the Internet and social media, can be employed to increase coverage. Many people turn to the Internet for health information.[108] In fact, half of adults who go online to "figure out" a medical condition subsequently visit a health care provider.[109] The internet is also a way to reach families that may be geographically or socially isolated or not active users of the medical system.[110] Many websites exist where reliable vaccination information can be found and they are often sponsored by governmental, nonprofit or academic sources.[111] These websites can be used to provide information that helps families know their child's risk for a vaccine-preventable disease, that their child is in need of the vaccination, and to identify information regarding vaccine efficacy and safety. The Internet can also be used to provide information and decision aids to parents in an interactive format to help them make vaccine decisions.[112] These decisions aids have been shown to improve understanding and the quality of decisions, including reducing uncertainty and regret, across a wide range of health decisions including those involving vaccines.[113]

Building upon the resources available in traditional internet pages, Web 2.0, or the second generation of the Internet, is beginning to be harnessed to promote vaccination by leveraging interactions across communities. Web 2.0 differs from traditional internet content which is "read only," by allowing interaction between participants as well as user-generated content.[114-116] Examples of Web 2.0 include social networking sites such as Facebook or Twitter, video-sharing sites like YouTube, and other media like blogs or forums.[114] A quarter of internet users with specific health concerns or goals have enlisted the internet to connect with others in similar situations.[4,108] There are, however, limited studies using Web 2.0 for health interventions in any setting including vaccination.[114] One study of adults showed that those who had been vaccinated against influenza thought that Facebook and Twitter were potentially useful vaccine communication channels.[117]

Due to the interactivity of Web 2.0 sites, the success of interventions around vaccination using this platform depends upon aligning the intervention strategy with public access to and use of these sites.[118] More information is needed to understand how people access and use these sites for vaccine information in order to create effective interventions.[118] To most effectively amplify the public and individual health benefits of social media, interventions using Web 2.0 may be most successful if structured around well-established models of behavior change. Additionally, although much attention focuses on the content being disseminated, Web 2.0 provides an ideal tool to foster peer support and modeling, as opposed to simply delivering information, two approaches likely to motivate targeted health behaviors.[119]

While the Internet and social media may be used to promote vaccination, at the same time these tools are being used to promote anti-vaccination messages, and these messages can spread rapidly.[120,121] For example, college students who viewed negative online blogs about the HPV vaccine had more negative attitudes regarding the vaccine, including perceiving the vaccine as less safe. Especially concerning, they had reduced intentions to receive the vaccine. Exposure to a positive blog did not alter vaccine-related risk perceptions, attitudes or intentions.[122] Another study tracked the HPV vaccination debate on MySpace and found slightly more positive blogs, but negative blogs focused on vaccination risks and were supported largely by vaccine-critical commentaries, rather than evidenced-based information.[123]

Health care providers need to be attuned to the content of vaccine-related websites since patients and families may view these sites and have questions,[121-124] especially given the common lack of verification of posted information.[125] Additionally, public health organizations can combat vaccine misinformation by providing reliable evidenced-based information in Web 2.0 forums.[120,123,126,127] Internet searches and tweets have been used recently to track outbreaks of diseases such as influenza.[128] This field of research, called infodemiology, which collects and analyzes data in near real time,[115] could also be used to assess what are the most common concerns regarding vaccination in different areas or among different populations, which could then be used to design a specific social or other media campaigns. For example, a recent study used publicly available data from 101,853 users of online social media to measure the spatio-temporal attitudes toward a new vaccine and revealed that information tended to flow between like-minded individuals. Simulations of infectious disease transmission also showed that if clusters of negative vaccine sentiments led to clusters of unprotected individuals, the likelihood of disease outbreaks would be greatly increased.[129] Public health officials could reframe negative vaccine messages into salient, evidence-based ones that are meaningful to parents. These messages might then propagate through the anti-vaccine community through social media, like Twitter, attenuating vaccine resistance. While such examples raise the intriguing possibility of leveraging Twitter and other social media to improve vaccination rates, further study is needed to define ideal strategies for program implementation and to document benefit. However, the growing adoption of Twitter and other social media by state health departments suggests that these tools, if successful, may one day become a standard part of public health communication directed at vaccine promotion.[130]

Conclusions

Multiple established and emerging strategies have been implemented to foster vaccination and understanding of vaccines at

the level of the family, provider, health system and community. New research is increasingly demonstrating the potential benefits of novel approaches such as text messages to transform how reminder/recall is implemented. At the same time, clinical decision support has demonstrated efficacy in multiple practice settings in preventing missed opportunities for vaccination. For communities, social media including Twitter may one day help health systems and public health departments more effectively challenge vaccine misinformation, while concurrently tracking outbreaks. As more is learned about each of these approaches in isolation, research should increasingly turn to understanding how best to integrate community, family, and provider-directed approaches that may synergistically reduce the tragic consequences of vaccine-preventable disease. This combined approach is likely to prove most effective in reaching the goals of Healthy People 2020 and limiting outbreaks of vaccine preventable diseases that continue to be observed in the United States.

Disclosure of Potential Conflicts of Interest

MSS has no financial disclosure to disclose. AGF is a co-inventor of the "Care Assistant" that provides clinician-focused, point of care decision support. He holds no patent on the software and has earned no money from this invention. No licensing agreement exists.

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