Improving vaccine registries through mobile technologies: a vision for mobile enhanced Immunization information systems

RECEIVED 2 March 2015
REVISED 25 April 2015
ACCEPTED 5 April 2015
PUBLISHED ONLINE FIRST 15 June 2015

Kumanan Wilson[1,2], Katherine M. Atkinson[2], Shelley L. Deeks[3,4], Natasha S. Crowcroft[3,4,5]

ABSTRACT

Immunization registries or information systems are critical to improving the quality and evaluating the ongoing success of immunization programs. However, the completeness of these systems is challenged by a myriad of factors including the fragmentation of vaccine administration, increasing mobility of individuals, new vaccine development, use of multiple products, and increasingly frequent changes in recommendations. Mobile technologies could offer a solution, which mitigates some of these challenges. Engaging individuals to have more control of their own immunization information using their mobile devices could improve the timeliness and accuracy of data in central immunization information systems. Other opportunities presented by mobile technologies that could be exploited to improve immunization information systems include mobile reporting of adverse events following immunization, the capacity to scan 2D barcodes, and enabling bidirectional communication between individuals and public health officials. Challenges to utilizing mobile solutions include ensuring privacy of data, access, and equity concerns, obtaining consent and ensuring adoption of technology at sufficiently high rates. By empowering individuals with their own health information, mobile technologies can also serve as a mechanism to transfer immunization information as individuals cross local, regional, and national borders. Ultimately, mobile enhanced immunization information systems can help realize the goal of the individual, the healthcare provider, and public health officials always having access to the same immunization information.

Key words: vaccines, surveillance, public health policy, mobile technology, epidemiology

INTRODUCTION

Immunization information systems (IIS) and registries are critical to the success of immunization programs.[1] However, there are many emerging challenges to the effectiveness of these systems including the increasing mobility of individuals, new vaccine development, use of multiple products, and the shift towards multiple immunization providers in several jurisdictions. New technological developments offer the opportunity to overcome these challenges. Smartphones and their corresponding software applications (apps) provide a unique mechanism to enhance patients' engagement with their healthcare and improve reporting of health information while addressing the aforementioned system challenges. There is also an opportunity to address knowledge barriers in users and increase access to health information. Building on the experience of developing Immunize CA, a national, bilingual immunization application for Canada,[2] we describe the opportunities for mobile technologies to improve vaccine programs and IISs with the vision of creating a system where individuals, physicians, and public health officials all have real-time access to the same information with the goal of improving patient care.

THE NEED FOR MOBILE ENHANCEMENT

Two recent changes have challenged existing mechanisms for tracking vaccine information. The first of these is the increasing fragmentation of the administration of vaccines in several jurisdictions. Once a service only provided by physicians or public health, individuals may now receive immunizations from multiple providers and at many delivery locations, such as pharmacies.[3] The second issue is the increasing mobility of individuals. Over a lifetime, vaccine recipients may have moved or traveled across regional or national borders. As a consequence, it is increasingly difficult for a single healthcare provider to possess a comprehensive immunization record for an individual and for individuals to also hold this information. These changes have occurred against a background of drift in vaccine policy and increasingly frequent changes in the combination of vaccines available in each jurisdiction and the schedules in which they are delivered. Further challenging IISs are the importance of understanding vaccine safety and effectiveness through real-time surveillance of adverse events following immunization (AEFIs) and linking vaccinations administered to their specific lots.

Mobile phones have already demonstrated the capacity to improve immunization practice. Recall/reminder text messages have been shown to increase immunization coverage in both pediatric and adult populations.[4–6] However, text messaging on mobile telephones is subject to character restrictions, limiting the capacity to deliver information. Text messaging also requires having the recipient's current mobile telephone number, which can be challenging over time.[4] Other technologies, such as web-based personally controlled health management systems, have been shown to significantly increase consumer participation in preventative health activities, such as influenza vaccination.[7] Another web-based tool aids physicians and public

Correspondence to Dr Kumanan Wilson, The Ottawa Hospital, Civic Campus, 1053 Carling Avenue, Administrative Services Building, Room 1009, Box 684, Ottawa, Canada ON K1Y 4E9; kwilson@ohri.ca; Tel: 1-613-798-5555 ext. 17910

 For numbered affiliations see end of article.

health personnel in selecting the most appropriate pediatric vaccinations to purchase for their patients, accounting for release of new combination vaccines.[8] We believe that smartphone apps will offer the advantages of web-based systems with the convenience and portability of mobile phones while mitigating some limitations of each platform for improving immunization practice.[9]

Based on our experience developing, releasing, and evaluating the impact of a national immunization app for Canada, we have identified several opportunities for mobile technologies to enhance ISSs which, if realized, could improve both patient care and program evaluation efforts. ImmunizeCA is a free smartphone application available for Android and iOS platforms, which currently functions as a digital tool for individuals to track their own and their family's immunizations as well as access information on vaccination and view outbreaks of vaccine preventable diseases in their area. A custom immunization schedule is generated for each profile in the app using user-entered demographic information and the embedded jurisdictional immunization schedule. Each vaccination encounter (e.g., 2-month visit) displays the recommended, publicly funded vaccinations, antigens covered, and displays plain language information on the vaccinations. Once the user indicates the vaccination as received, it is recorded as part of the digital health record, which resides on the device, and can also be emailed, printed, or backed up to iCloud or Google Drive. As of March, 2015, ImmunizeCA had 80,000 downloads and 1.2 million page views. We have embarked upon pilots of mobile reporting of immunization status, mobile reporting of AEFIs, and proof of concept bar code scanning using commercially available smartphones to explore how to best leverage the user facing solution to improve program delivery and evaluation. We have also described how the app can overcome jurisdictional obstacles to a coordinated immunization policy by providing tailored information by the local, regional, and national level.[10]

How a System Could Work

The ultimate goal of a mobile-enhanced IIS is to create a system where the same immunization data resides with the individual, their healthcare provider and public health officials at all times. In this scenario, the individual can experience the best care. The system could also permit individuals to report AEFIs and also have lot-specific barcode information associated with their vaccination records. We envision 3 phases in the implementation of a mobile enhanced IIS.

PHASE I: UNIDIRECTIONAL FLOW OF PROOF OF IMMUNIZATION FROM A MOBILE APPLICATION TO AN IMMUNIZATION INFORMATION SYSTEM

To overcome fragmentation of vaccination provision and mobility of individuals, IISs need to develop mechanisms for an individual to accurately and rapidly communicate immunization history. In Ontario under the Immunization of Schools Pupils Act, parents are responsible for reporting their child's immunization records to their local public health unit for school entry and students who do not have up-to-date immunization records on file may be suspended until records are provided. Having complete and accurate immunization histories is also crucial in the event of outbreaks and can prevent duplicate vaccination, which minimizes risks of side effects and costs.

Mobile devices are capable of securely communicating with web services and other information repositories, presenting an opportunity to facilitate rapid and complete reporting of immunization status. Progress has been made in developing transmission and data standards such as health level 7 and SNOMED CT[11] which could be applied to ensure proper exchange of standardized data, which will ensure long term usability and applicability across multiple (potentially international) systems.

PHASE II: BIDIRECTIONAL FLOW OF DATA BETWEEN MOBILE APPLICATIONS AND IIS

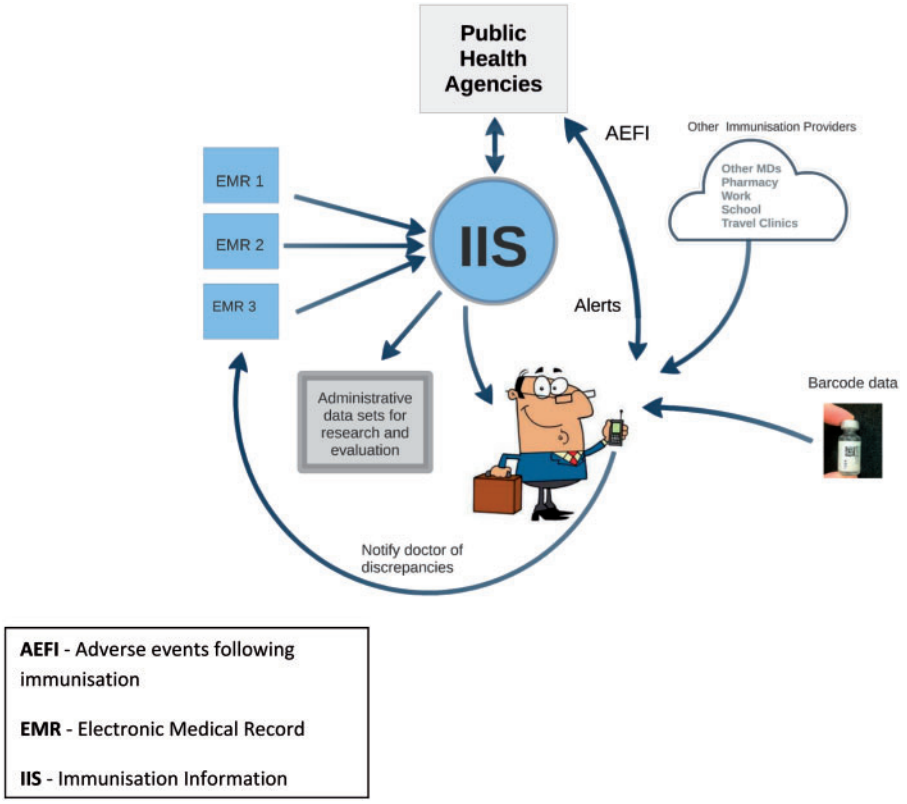
Once unidirectional data flow is established and evaluated, IISs will also need to provide a direct mechanism for immunization status held by public health officials to be accessible to individuals. To achieve this goal, ensuring that vaccination status is available to patients, authenticated data residing in the IIS should flow and be downloaded onto the users' device. Alternatively, an individual's app could provide access to a mirror version of the data in the IIS, leaving the IIS data as is; this is routinely practiced in mobile banking. This would allow for identification of discrepancies in data sets, and individuals would then be able to submit proof of vaccination not currently present within the IIS. A mobile portal could also be designed to enable validation of new information by immunization providers. Alternatively, a healthcare provider could validate the information being entered directly through an individual's app using a signature function and corresponding secure PIN. Once information has been validated it would be secured such that the user cannot retrospectively alter it and the data could then flow into the repository. When immunization records are consolidated from multiple sources, successfully validated, all parties will have access to the most accurate record, which can then be reliably used to facilitate care.

PHASE III: ANCILLARY FEATURES TO COMPLEMENT SURVEILLANCE

Bidirectional communication between a user-facing application and an information repository to facilitate reporting of immunization status may help mitigate some of the challenges being faced by Canadian immunization programs. This infrastructure could also be leveraged as a spontaneous reporting system, which permits the inclusion of reports on individual's post immunization experience accompanying their immunization status. This could include reports of suspected AEFIs to their public health unit that would help generate safety signals improving safety surveillance in IISs. Algorithms to examine these reports could be implemented to trigger notifications for any reports, which are categorized as severe. Providing the option of completing surveys via smartphones may help to expedite collection of additional or follow-up information. Mobile reminders may also improve response rates in outbreak settings.[12] Allowing vaccinees to report AEFIs in this manner would need to be evaluated to ensure the usefulness of these reports.[13] We have piloted the use of an app to report AEFIs following influenza vaccination in healthcare workers.

Adverse event reporting and proof of immunization could be further enhanced and potentially validated by mobile scanning of the global standard 2D barcodes, which are increasingly present on vaccine vials.[14] Mobile scanning would facilitate the upload of the DIN/GTIN vaccine information of administered vaccines directly to an individual's app records, linking any AEFIs to a specific lot administered. This may provide repositories with more detailed vaccination information as not all EMRs are equipped to scan the barcode labels, and manual recording can introduce errors and limits the ability to link the lot specific information to the vaccination report.[15] This level of detailed information would also allow for universal product identification regardless of semantics utilized at point of care. This is especially useful across organizational or national boundaries, which may be operating in a variety of languages or data models. Accurate product identification can then be used for tailored

Figure 1: Vision of how mobile devices could enable a comprehensive immunization registry. AEFI, adverse events following immunization; EMR, electronic medical record; IIS, immunization information.



clinical decisions, such as adjusting dose scheduling of vaccinations if an individual were to switch providers mid-series. If an issue with a specific lot was identified retrospectively, users could be notified whether any family member received a vaccine from that lot and of any specific action required.[16] Bar code scanning enabled by smartphones could also have implications for assessing vaccine effectiveness and failures in the event of vaccine preventable disease cases or outbreaks.

BARRIERS TO A MOBILE APP SERVING AS A CRITICAL COMPONENT OF AN IMMUNIZATION INFORMATION SYSTEM

Privacy Issues

Flowing personal health information bidirectionally between mobile devices and an IIS will require careful evaluation to ensure compliance with regional privacy legislation. Ensuring privacy compliance as well as authentication will likely involve some combination of data encryption, unique identifiers, informed consent, and validation systems to ensure that information is being transmitted to the correct sources. Mobile devices, however, offer some advantages with respect to privacy and security. If an individual were to lose a mobile device, with some operating systems the device can be located and remotely wiped, removing any information stored locally.[17] Mobile devices and individual apps can also be password protected to protect any health information they contain. Recent addition of fingerprint authentication on smartphones also provides a potential further level of security, which surpasses password protection. In this respect, mobile devices offer significantly higher levels of security than current solutions such as paper vaccination records.

Access and Engagement Issues

Since smartphone apps are only usable for individuals with devices, such a solution to immunization record tracking may not achieve adequate population level representation to be used for national coverage estimates. A possible solution is to create a complimentary web portal or HTML-5 software version of the app that is accessible via kiosks, public, or personal computers, in addition to smartphones so access is universally publically available, regardless of device. Ultimately, whether a mobile enhanced solution is adopted will depend on the willingness of all sections of the public to utilize the option and, importantly, on the willingness of the user to consent to share their data with public health officials. This will be dependent on designing a solution, which fits patient information needs, preferences, and adheres to their values of security of health information, and the ability of public health officials to raise awareness of the mobile option. However if adopted, patient engagement with the mobile solution could be amplified through the use of personalized notifications and features such as identifying the need for travel vaccinations when individuals book travel online or producing tailored vaccine schedules for special medical conditions.

While mobile technologies are pervasive, there are still individuals who are uncomfortable sharing personal health information through technology. In many successful IISs an opt-out system exists where immunization data would be shared unless an individual objects.[18]

Table 1: Characteristics of vaccine registries globally and opportunities for a mobile solution

Immunization Registry Characteristic (Adapted from[21])	Mobile Solution
Collect data on vaccines provided	Have individuals record vaccines received in a standardized structure[22] on a mobile device and transmit information to an IIS
Generate reminders and recall vaccination notices for each client	Local notifications for upcoming appointments, which can sync with smartphone calendar to generate reminders. Recall notifications can be sent directly from IIS to affected individuals mobile devices
Consolidating vaccination records of all immunization clients from multiple vaccination providers	Data from multiple sources can be inputted or flowed into an app. Consolidation can occur at the individual or IIS level
Access to complete records of all previous vaccinations makes it easier for the healthcare provider to ensure that individuals receive recommended vaccines	User can share records with health care provider and can also potentially download from the IIS. This could reduce barriers to vaccinating individuals such as accessing immunization history and consent forms.[23]
Allow vaccination coverage assessments	Mobile apps could be a compliment to existing systems by consolidating data from multiple vaccine providers and shared with an IIS
Increase and sustain high vaccination coverage through identification of pockets of unvaccinated individuals or groups and serve as a basis for tailored vaccination campaigns	A comprehensive IIS can identify areas or vaccines with suboptimal coverage at both a national and subnational level.[24] A global positioning system (GPS) enabled mobile app allows for a direct tailored vaccination campaigns (delivering local or push notifications) to individuals in a specified geographic area; enabled by geofencing technologies.[25]
Future scope, including safety	Integration with barcoding enables alerts for expired vaccines, cold chain breaches, recalls. Linking with AEFI reporting could be enabled.

Such a system could be employed with a mobile app or consent could be explicitly requested. In either scenario the responsibility would reside with public health officials to provide an incentive for individuals to use the app and share their data. This would include the recognition of the virtual record as being official, facilitating proof of vaccination status, financial incentives, or providing information of value back to the individuals such as recall reminders.[19,20]

While the solution we have presented is meant to complement existing systems in high-income countries there is potential value for low- and middle-income countries. A short message service (SMS)-based version delivered using standard cellphones could be developed to facilitate reporting of vaccination status in these countries. Given the high penetration of cell phones in many developing countries, an SMS-based solution could improve equity and access to immunization as pockets of underserved regions could be quickly and easily identified.

CONCLUSIONS

The timely and accurate collection and transmission of information regarding immunization status has enormous value for individuals, vaccine providers, public health officials, and industry. If effectively managed, this information can be utilized to ensure the highest quality of patient-centered care as well as ensuring that programs are evaluated and tailored to meet end user needs in real-time. The advent and maturation of mobile technologies pose an opportunity to address gaps within existing IISs. They offer a solution which caters to mobile individuals and consolidates proof of immunization obtained through multiple providers. This mobile vision incorporates the core characteristics of a traditional IIS while providing a platform for engagement with their own health information, which could be applied to multiple health care settings (Table 1). Further implementation and evaluation research are warranted.

FUNDING

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

COMPETING INTERESTS

K.W. and K.A. are both co-founders of Sigvaria Mobile Technologies Inc. who developed ImmunizeCA for the Ottawa Hospital Research Institute and the Canadian Public Health Association.

CONTRIBUTORS

K.W. and M.A. provided the preliminary draft of the manuscript, S.L.D. and N.C. provided critical revisions and feedback on manuscript design. All authors gave final approval on the submitted version. There were no additional contributors.

REFERENCES

1. Johansen K, Lopalco PL, Giesecke J. Immunisation registers–important for vaccinated individuals, vaccinators and public health. *Euro Surveill.* 2012; 17(16):pii=20151.
2. ImmunizeCA App. ImmunizeCanada. http://immunize.ca/en/app.aspx. Accessed March 20, 2014.
3. Goad JA, Taitel MS, Fensterheim LE, Cannon AE. Vaccinations administered during off-clinic hours at a national community pharmacy: implications for increasing patient access and convenience. *Ann Fam Med.* 2013;11(5): 429–436.
4. Stockwell MS, Fiks AG. Utilizing health information technology to improve vaccine communication and coverage. *Hum Vaccin Immunother.* 2013;9(8): 1802–1811.

5. Leeb A, Regan AK, Peters IJ, Leeb C, Leeb G, Effler PV. Using automated text messages to monitor adverse events following immunisation in general practice. *Med J Aust.* 2014;200(7):416–418.
6. Regan AK, Blyth CC, Effler PV. Using SMS technology to verify the safety of seasonal trivalent influenza vaccine for pregnant women in real time. *Med J Aust.* 2013;199(11):744–746.
7. Lau AY, Sintchenko V, Crimmins J, Magrabi F, Gallego B, Coiera E. Impact of a web-based personally controlled health management system on influenza vaccination and health services utilization rates: a randomized controlled trial. *JAMIA.* 2012;19(5):719–727.
8. Jacobson SH, Sewell EC. A Web-based Tool for Designing Vaccine Formularies for Childhood Immunization in the United States. 2008. *J Am Med Inform Assoc.* 2008 Sep–Oct; 15(5): 611–619.
9. Clark SJ, Butchart A, Kennedy A, Dombkowski KJ. Parents' experiences with and preferences for immunization reminder/recall technologies. *Pediatrics.* 2011;128(5):e1100–e1105.
10. Wilson K, Atkinson K, Keelan J. Using mobile technology to overcome jurisdictional challenges to a coordinated immunization policy. *Health Affairs Blog.* 2014. http://healthaffairs.org/blog/2014/11/14/using-mobile-technology-to-overcome-jurisdictional-challenges-to-a-coordinated-immunization-policy/. Accessed December 10, 2014.
11. Benson T. Principles of health interoperability HL7 and SNOMED. Springer; 2010. Dordrecht, Netherlands.
12. Simone B, Atchison C, Ruiz B, *et al.* Investigating an outbreak of Clostridium perfringens gastroenteritis in a school using smartphone technology, London, March 2013. *Euro Surveill.* 2013;19(19): pii=20799.
13. Braun MM. Vaccine Adverse Event Reporting System (VAERS). Usefulness and Limitations. Insitute for Vaccine Safety. 2006. http://www.vaccinesafety.edu/VAERS.htm. Accessed October 5, 2014.
14. Centers for Disease Control and Prevention. Immunization Information Systems (IIS). Two-Dimensional (2D) Vaccine Barcodes. http://www.cdc.gov/vaccines/programs/iis/2d-vaccine-barcodes/. Updated May 7th, 2014. Accessed June 20, 2014.
15. Bernal-González P, Navarro-Alonso J, Pérez-Martín J. Computerised vaccination register for the Murcia region, Spain, 1991 to 2011. *Immunisation Registers.* 2012;21:pii=20150.
16. Maurer W, Seeber L, Rundblad G, *et al.* Standardization and simplification of vaccination records. *Expert Rev Vaccines.* 2014;13(4):545–559.
17. Apple Inc. Find My iPhone, iPad and Mac. http://www.apple. com/ca/icloud/find-my-iphone.html. Accessed September 1, 2013.
18. Chin LK, Crawford NW, Rowles G, Buttery JP. Australian immunisation registers: established foundations and opportunities for improvement. *Euro Surveill.* 2012;17(16):pii=20148.
19. Szilagyi PG, Bordley C, Vann JC, *et al.* Effect of patient reminder/recall interventions on immunization rates: a review. *JAMA.* 2000;284(14):1820–1827.
20. Bassani DG, Arora P, Wazny K, Gaffey MF, Lenters L, Bhutta ZA. Financial incentives and coverage of child health interventions: a systematic review and meta-analysis. *BMC Public Health.* 2013;13 (Suppl 3):S30.
21. Pebody R. Vaccine registers–experiences from Europe and elsewhere. *Euro Surveill.* 2012;17 (17):pii=20159.
22. Brown DW, Gacic-Dobo M, Young SL. Home-based child vaccination records–a reflection on form. *Vaccine.* 2014;32(16):1775–1777.
23. Moss JL, Feld AL, O'Malley B, *et al.* Opportunities for increasing human papillomavirus vaccine provision in school health centers. *J School Health.* 2014;84(6):370–378.
24. van Lier A, Oomen P, de Hoogh P, *et al.* Praeventis, the immunisation register of the Netherlands: a tool to evaluate the National Immunisation Programme. *Euro Surveill.* 2012;17(17):pii=20153.
25. Wilson K, Atkinson K, Deeks S. Opportunities for utilizing new technologies to increase vaccine confidence. *Expert Rev Vaccines.* 2014 Aug;13(8): 969–977.

AUTHOR AFFILIATIONS

[1]Departments of Medicine and Department of Epidemiology and Community Medicine, University of Ottawa, Ottawa, Canada

[2]Clinical Epidemiology Program, Ottawa Hospital Research Institute, Ottawa, Canada

[3]Public Health Ontario, Toronto, Canada

[4]Dalla Lana School of Public Health, University of Toronto, Toronto, Canada

[5]Laboratory Medicine and Pathobiology, University of Toronto, Toronto, Canada