Vaccination Monitoring System

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Abstract— *Vaccination is an essential component of modern public health programs and is among our most cost-effective medical interventions. Yet despite vaccines' clear effectiveness in reducing risks of diseases that previously attacked large proportions of the population, caused many deaths, and left many people with permanent disabilities, current vaccination policies are not without controversy. Vaccines, like all other pharmaceutical products, are not entirely risk-free and door to door vaccination program such as the famous pulse polio vaccination program may not be very effective if the vaccination is not maintained in proper environment. An efficient tracking system is also required for such vaccination program to ensure that all the people are able to avail the benefits of such vaccination program.*

The idea of vaccine monitoring is applicable in under developed (Africa) and developing nations (like India) where the vaccines storage environment (temperature) tracking is a big problem. When the environment is not optimal(temperature is not within the expected range or there is too much of light exposure or any other factors which may deteriorate the quality of the vaccine), the efficacy of these vaccines is lost. All the health worker carries is a portable box with some cold pads (door to door polio vaccine campaign). Our connected maraca has to help ensure the safety and efficacy of the vaccines. While the traveling health workers go around, based on the vaccine type and recommended environment setting, sensor data will be sent to the cloud. Over the cloud using the received data, we can monitor the vaccine storage environment to ensure that it is stored properly under prescribed condition. Also, the data will help us determine if a health worker has not followed the best practices, and take actions accordingly. Also, using smartphones and cloud, health workers can be prevented to administer spoiled vaccine. This idea can be extended to efficient storage and handling of other environment-sensitive medicines as well.

I. INTRODUCTION

The efficacy of stored vaccine is critically dependent on storage and handling practices, including the use of reliable temperature monitoring methods and properly controlled storage systems. The absence of those protections can result in substantial waste, diminished vaccine potency, and the need for revaccination. Many vaccines must be stored at low temperatures, some below -15°C, and others between 2 and 8°C. If vaccines are not stored correctly they can lose their effectiveness.

According to the Center for Disease Control, failure to adhere to recommended specifications for storage and handling of immunobiologics can reduce or destroy their potency, resulting in inadequate or no immune response in the recipient. Maintenance of vaccine quality is the shared responsibility of all handlers of vaccines from the time a vaccine is manufactured until administration and distribution.

According to the Immunization Action Coalition, all vaccines should be stored in a refrigerator or freezer that is designed specifically for the storage of biologics or, alternatively, in a separate dedicated unit. A dorm-style combination refrigerator-freezer unit with just one exterior door has been shown to be unacceptable no matter where the vaccine was placed inside the unit. Stand-alone refrigerator or freezer units are best for storage needs.

It is estimated that $20 million is wasted annually from poor refrigeration and storage environment, and up to 35% of vaccines are affected by improper storage. Accurate and uniform temperature in a refrigerator and limited light exposure plays a key role in ensuring the life of vaccines, reagents and other biological. Research has shown that minor variances in temperature such as those in a household refrigerator can compromise the effectiveness of your biological, risking up to thousands of dollars in valuable contents. These high values of loss,coupled with today's requirements and guidelines, make it essential to use proper refrigeration equipment designed for vaccine storage.

II. LITERATURE SURVEY

During a literature survey we collect some of information about the vaccination storage management system for city and rural areas across various countries, we found the following

Study 1: Hepatitis B (HB) vaccine delivery outside the cold chain: the Long-An county, China example. Global Perspectives on Hepatitis. International Task Force on Hepatitis B Immunization[4].

This study was performed in China and sponsored by China's Expanded Programme for Immunization (EPI). The study included a research component designed to explore mechanisms for integrating HB vaccine into the immunization schedule. In Long-An County, the majority of births (80.5%) occur at home and are attended by village midwives or 2 village doctors. In the program, vaccine administered by village midwives was delivered to the home of each midwife on a quarterly basis for storage at room temperature. The plasma-derived HB vaccine administered by the village doctors was maintained in cold storage until given to the infant within 72 hours after birth. The village doctors were notified of the births by the village midwives within 12 hours of delivery. [3]The second and third doses of HB were given with other EPI vaccines as part of mobile outreach services.4 A sero-survey was performed to examine the seroconversion rate of HB antibody in babies who received a birth-dose vaccine stored at room temperature versus under refrigeration. The survey was performed after the infants had received the three doses of HB vaccine. The study group included 590 infants aged 10 to 20 months. Of the study group, 358 infants received their birth dose from vaccine stored at ambient temperatures and administered by a village midwife, and 232 infants received vaccine stored in refrigerators and administered by a village doctor. The seroconversion rate was 81.6% in the OCC group and 81.9% in the refrigeration group. Maternal HB surface antigen (HBsAg) rates were 15.4% and 20.7% respectively. There was no difference between HBsAg rates amongst vaccinated infants in the OCC and refrigeration groups (1.1% vs. 2.2%). All HBsAg positive infants were born to HBsAg positive mothers. The estimated protective efficacy of vaccination (the percent reduction in HBsAg attributable to vaccination amongst infants exposed to HB virus) was similar at 84.5% and 77.8%, respectively in the two groups.4,5 Preliminary findings in this study demonstrated that HB vaccine stored OCC for up to three months can remain effective and be delivered to infants at birth.

Study 2: Home delivery of heat–stable vaccines in Indonesia: outreach immunization with a prefilled, single-use injection device. Sutanto A, Suarnawa IM, Nelson CM, Stewart T, Soewarso I. Bulletin of the World Health Organization. 1999.

A study conducted from July 1995 to April 1996 in the Indonesian Islands of Lombok and Bali involved 110 midwives in the delivery of HB vaccine to infants and tetanus toxoid to their mothers.6 During the study, instead of standard disposable syringes with multidose vials, village midwives used the Uniject® device a prefilled, single-dose, autodisable injection device. Provincial and district supervisors trained the midwives prior to the study. All Uniject injections were given at the homes of newborn infants. Questionnaires and interviews were used to gather data from mothers and midwives. The plasma-derived HB was distributed from the Indonesian vaccine manufacturer Perum Bio Farma, and was kept under normal cold-chain conditions during transport and storage at the health centers. After the midwives had picked up supplies of vaccine-filled Uniject devices at the health centers, they were allowed to keep them under ambient conditions for up to one month. A potency test and a serological analysis were conducted during the study to ensure safety and efficiency of the storage strategy. Training and a threshold heat indicator were also used to prevent heat exposure. The threshold heat indicator was attached to each box to determine if the vaccines were exposed to damaging temperatures. The heat indicator changed color when exposed to temperatures 49°C. Infants received the birth dose of HB vaccine delivered either with a standard syringe and vaccine stored in the cold chain, or with the Uniject device prefilled with vaccine stored for one month OCC. Seroconversion rates were identical for the two groups.

Study 3: Use of cool water packs to prevent freezing during vaccine transportation at the country level. Kartoglu U, Ganivet S, Guichard S, et al. PDA Journal of Pharmaceutical Science and Technology.

VVMs were used as an indicator of excess heat and freeze exposure in a study that evaluated the use of cool water packs to prevent freezing during transportation at the country level. Part of the study was conducted in a laboratory setting and part in Nepal, Myanmar, Turkey, and Zimbabwe to show temperature variations in a real life situation. The study used different cold boxes, vaccine carriers, data loggers, and all four types of VVMs (VVM2, VVM7, VVM14, and VVM30).16 In laboratory studies, either dummy vials with VVMs and real vaccines were loaded into various sized cold boxes and vaccine carriers with water packs that had been cooled overnight at 2° to 8°C. The boxes and carriers were then kept at ambient temperatures of 32°C and 43°C. In country studies cold water packs, prepared as described above, were used to distribute vaccines during routine distribution. In addition, dummy vials labeled with four different types of VVMs were included in some loads. In both studies, the temperatures inside the carriers were measured, and VVM progression was noted. A method was developed to estimate remaining shelf life of vaccines using VVM readings. Recorded temperature data were used to calculate the amount of the VVM shelf life that had expired. 7 The study showed that large vaccine carriers at extreme ambient temperatures of 43°C could prevent temperatures rising much above +20°C over 48 hours, and VVM7, VVM14, and VVM30 maintained reasonable remaining shelf lives (all vaccines fall into these categories, except for OPV). These results provide further evidence that VVMs can be effectively used to manage vaccine stock and ensure efficacy of vaccines that are transported outside of a traditional cold chain[5].

III. PROBLEM DEFINITION

A vaccine storage facility is very poor in most parts of the under developed and developing countries. Because of low number of refrigerators for vaccine storage and use of cheap portable vaccine storage equipments, the efficiency and quality of the vaccine deteriorate over time. The challenges in the present system are:

(i) Rural area do not have sufficient amount of storage equipments.

(ii) Rural area do not have a good facilities for transportation or vaccine.

(iii) Storage and trasportation of large units of vaccine which are kept refrigerated at 2 to 8 °C , with maximum permitted storage periods of 35 to 42 days.

(iv)Vaccines are sensitive biological substances that can lose their potency and effectiveness if they are exposed to temperatures (heat and/or cold) outside the required temperature range of +2 °C to +8 °C or when exposed to light.

(v) Freezing refers to a situation where vaccines experience temperatures at or below 0 °C. Vaccines may not appear frozen but may have been damaged at these temperatures. Most vaccines are considered to be damaged at 0 °C.

(vi) Failure to adhere to cold chain requirements may reduce vaccine potency, resulting in lack of protection against vaccine preventable diseases and/or increased local reactions after administration of vaccine.

(vii) The loss of vaccine effectiveness due to cold chain exposures to adverse conditions is cumulative, permanent and irreversible.

(viii) Individuals who are immunized with exposed vaccines often need to be recalled by their health care provider and reimmunized to ensure that they are protected against the specific vaccine preventable disease(s).

(ix) Vaccines may be wasted if they have been exposed to temperatures below +2 °C and/or above +8 °C or if they are not used prior to the expiry date.

(xi) Vaccine wastage results in increased costs (to replace the wasted vaccines, human services and specialized transportation).

(xii) With the globalization of the vaccine manufacturing industry, and intermittent global vaccine shortages, it is not always possible for Ontario to quickly obtain additional quantities of vaccines to replace vaccine that is wasted.

We Proposed an efficient vaccination monitoring system using sensors, cloud computing concept with mobile SMS facilities with the aim of ensuring that everyone has access to safe vaccine. The vaccination monitoring system should solve the issue of ensuring that the door to door vaccination reaches every door in the given area with all safety measures and limited wastage of vaccine .

IV. PROPOSED SOLUTION & METHODOLOGY

In this paper the concepts of autonomic vaccine monitoring are revisited which defines a set of architectural characteristics to manage a system, where complexity is increasing but must be managed without increasing cost or the size of the management team, where a system must be quickly adaptable to new technologies integrated to it, and where a system must be extensible from within corporation out to the broader ecosystem and vice versa.

The primary goal of autonomic computing is that “System manage themselves according to an administrator goals .People living in rural area do not have access to proper vaccination storage system which leads to wastage of vaccines.In this paper, we propose the solution for monitoring vaccine storage to ensure optimal quality vaccine is delivered and we also implement mechanisms to ensure that all vaccination programs(door to door vaccination) reaches every door to ensure that everyone avails the benefit of vaccination.

At present the commercially popular solution is to only monitor the cold chains (statically installed freezers) to ensure proper storage of the vaccines. But the health workers need to go around on the field most of the time to administer the vaccines. Our application offers a solution to monitor the storage and safe keeping of the vaccines on the move. The recorded data also serves as a very important input for the scientists and engineers working on creating more environment-robust insulation box and vials. Our solution is economic as well. In case, the health workers need to go to remote areas, where Internet connectivity is absent, all the recorded data can be stored in the IoT device, to be pushed to the cloud in a batch, once the worker is back to connected area. Also, in the absence of Internet, anomaly detection algorithm running in the kit, can give a forewarning to the health worker immediately by turning on the buzzer.

In our project, a Raspberry Pi board with multiple sensors (temperature, light, gyro) attached to it, is running in a portable box with vaccines, which a health worker is carrying. The board can be connected directly to WiFi, or we can enable to Bluetooth to connect to the mobile phone of the worker. Sensor data recorded is processed in an anomaly detection algorithm inside the IoT board and if it detects environment anomaly, the buzzer starts sounding. The processed data is also periodically pushed to the cloud for further analysis. Analyzed data will send a live Push Notification to the mobile phone of the health worker, and his coordinator (a meaningful and informative message is displayed) to handle the crisis situation effectively. Crucial sensor data recorded inside the portable box is periodically pushed to the cloud. Cloud has enough resource to efficiently process the huge amount of data received. The data analysis done on cloud, is not possible to do in the IoT board. The insights received from the data analysis not only helps a health worker take corrective measures on time, but also promises the building of a better solution in the future. Multiple sensors are used to monitor the environment of the portable box carrying the vaccines. GPS sensors are also added to track the movement of the health worker, generating more insights. The amount of information gathered from the sensors in an absolutely non-intrusive way is very effective in such ground level scenarios. Usage of each sensor data: (i) Temperature==strict temperature range should be maintained, otherwise raise alert (ii) Light==Over exposure to light can spoil the vials, raise alert (iii) Gyro==if the vial is not kept in a proper position and if it is moving too much, it can go bad, raise alert . An Android app for the health worker: Each health worker gets money for administering a vaccine. This is one of his biggest incentive. After administering the vaccine, he will be using the app to register the administration. These registrations will be used to calculate his incentive. As soon as the IoT board detects a vaccine going bad, it will disable the registration of administering of that vaccine. This way, the health worker won't administer a spoiled vaccine, just for incentive. The Android app also shows the current position of the vaccination box as the volunteer carries it from door to door. This allows the administrator to ensure that the volunteer has covered all areas that were allotted to him. The Administrator can also see the values of the temperature, light intensity and orientation of the box using the app.

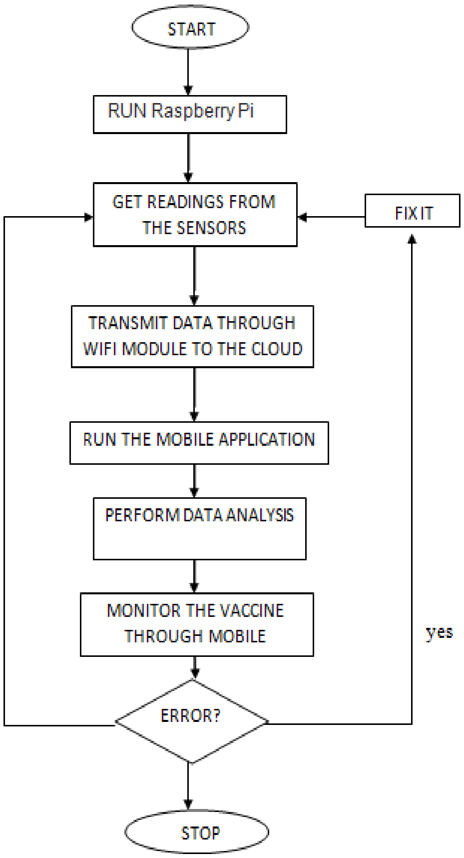

Fig 1: Flow diagram for working of vaccine monitoring

CONCLUSIONS

This paper shows the new working concept of vaccination storage monitoring system. Internet of things and computer technology is very famous in vaccine monitoring for its potentials and efficiency as well as quality of service. The device and the application is provided to all governmental and nongovernmental organizations. It plays a vital role better management of vaccines. The main objective behind this concept is to provide better facilities and ensure availability of superior quality vaccine at places where local bodies and health organizations do not have good facilities for storing vaccine for long time period. With the help of this new concept we can ensure that vaccine is stored properly and the distribution of the vaccine is properly monitored .Apart from this the fact that the administrator will also be able to keep track of the location and the condition of the storage facility supplements to our endeavor of ensuring availability of good quality vaccine.

REFERENCES

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