A systematic review on the use of technology in health: Insights from resource-poor settings

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Executive summary

In Bihar, one of the resource-poor states in India, reinforcement of the interventions to improve health and healthcare related indicators are in place for over a decade. Continued efforts from Government and non-Governmental developmental partners are trying to generate evidences and accumulate learning regarding successes or failures of these interventions. Thus, there is a need to ensure that these evidence-based lessons are processed appropriately into collective wisdom that can be imbibed into the Governmental system for relevant need-based policy/decision making. It is also important to ensure that logical pathway from data generation, its interpretation, contextualization and evidence generation to policy-making is well-understood, documented and advocated adequately in real-time. Given healthcare has become increasingly an information-driven domain, interventions that employ technology are likely to widen access, improve quality and increase service efficiency at a rapid pace. If applied appropriately, they can act as a complementary strategy for strengthening health system performance. Digitalization has facilitated countless advances in several low-and-middle-income countries (LMIC).

As a first step, a systematic review was conducted to provide a comprehensive snapshot of meaningful use of technology within relevant health system building blocks in LMIC including India. Probable reasons of e-health success and failure were also profiled in this review. We believe that lessons learnt from this evidence-base are important in developing framework for Bihar's own comprehensive e-health strategies. There are several successful implementations of digital innovations in health which can be easily adopted in Bihar.

For example, as observed in Sub-Saharan Africa and Bangladesh, childhood malnutrition can be reduced by generating real-time data through a central web- and SMS-based data collection platform on key maternal and child-health indicators. This real-time information can be utilized to identify areas with high burden of malnutrition so that delivery of community-based essential services can be enhanced in a timely manner. Taking example from Tanzania, family planning practices can be improved by imparting

knowledge through an automated, real-time, interactive and on-demand short message service platform. Peru, Brazil and Haiti showed how access to real-time patient-centred records at the point of care through the Internet and electronic medical record can successfully control multidrug resistant Tuberculosis or any other communicable disease even in remote and inaccessible areas. A web-based Hospital Management and Information System using a District Health Information System version 2 can streamline the operations and improve the efficiency of the public hospitals by providing real-time quality data on patient influx, treatment, human resources, inventory as reported in Myanmar and Gujarat. Internet and mobile technologies can be applied to improve health care utilization through "online" health service delivery as implemented in China. Tele-health including tele-medicine can be an alternative virtual platform to deliver quality services particularly in rural areas where access to hospitals are lacking. Human resource being one of the principal health system inputs, workforce management through a web-based app and e-service book can increase transparency, facilitate microlevel manpower planning and reduce inequalities as reported from Himachal Pradesh, India.

However, as health systems are highly complex social systems, there is no single set of best practices that can be adopted as an ideal model for improved performance in other settings. The success of one approach is determined by the underlying characteristics of the health system, local values and ideologies, all these supported by an enabling environment. The urge to use technology without proper identification of the priority health issues often led to frustrating failure. Therefore, before attempting to embed ICT into routine healthcare, it is essential to ensure that it meets real needs and provides clear value. Thus, it appears that there remains an appreciable need for conducting primary research on technology in Bihar and consequent implementation of the learning to ensure that through efficient technology-based collection, management, analysis and visualization of granular data in real time gets utilized into data-driven evidence based policy-making and program management so that public health service delivery can be reinforced through an organically developed platform.

Introduction

Despite significant progress in health, every year millions of people in poorer countries are dying from preventable and treatable conditions like Diarrhoea, Tuberculosis, Malaria and HIV. The worst affected are mothers and children. Everyday an estimated 830 women die of preventable pregnancy and childbirth related causes and approximately 15000 under-five (U-5) children die of prematurity, diarrhoea and pneumonia worldwide, particularly in developing countries[1, 2]. Non-communicable diseases contributes 37% deaths in low-resource settings[3]. For example, heart diseases killed 15 million people in 2015 and majority were reported from developing countries. Many low-to-middle-income countries are also experiencing the dual burden of both communicable and non-communicable diseases [4]. For example, Malaria killed about 1.2 million under-five African children and Tuberculosis affected 10.4 million during 2016 in Africa, India, China, Indonesia and Philippines. Provision of high-quality, affordable and universally accessible health-care remains a major public health challenge in developing countries[5, 6]. Some of the probable explanations might be paucity of information, questionable data quality, lack of resources, poor tracking and monitoring system[6].

Designing innovative ways to reduce the geographic and financial barriers to health appear to be the need of the hour. However, the solution may be a matter of scaling up access to simple approaches that are known to work if done correctly and in due time. For example, maternal and new-born deaths could be prevented by ensuring skilled care before, during and after birth, childhood diseases could be prevented through basic immunization and diarrhoea related deaths could be reduced with simple oral rehydration solution. This scaling-up of health services delivery can be achieved in many ways. However, one of the quickest and efficient ways is through application of information and technology (ICT)[7,8]. Several ICT projects launched in low-resource settings demonstrated impressive success[9]. Use of technology offers new opportunities to improve health-care access, continuity of care, knowledge and behaviours across a range of contexts and target groups at affordable costs[9]. Given greater penetration of low-cost mobile devices, wireless internets and broadband services, use of technology seemed a feasible option even in the remotest areas. It can also act as a complementary strategy for strengthening health system in poor-resource settings. For example, appropriate use of digital platform led to effective control of deadly diseases like HIV in Tanzania, Malaria in Cambodia[10] and Tuberculosis in Peru[11]. However, because of huge diversities in country's demographic profile, health systems performance and culture context, these ICT innovations were very country-specific. Thus, identifying factors derived from these successful projects will give us the direction in developing any new health innovation in

similar settings. However, published evidence on nationwide and scalable projects using technology in health are limited.

In Bihar, one of the resource-poor states in India[12], reinforcement of the interventions to improve health and healthcare related indicators are in place for over a decade. Continued efforts from Government and non-Governmental developmental partners are trying to generate evidences and accumulate learning regarding successes or failures of these interventions. Thus, there is a need to ensure that these evidence-based lessons are processed appropriately into collective wisdom that can be imbibed into the Governmental system for relevant need-based policy/decision making. It is also important to ensure that logical pathway from data generation, its interpretation, contextualization and evidence generation to policy-making is well-understood, documented and advocated adequately in real-time.

Given healthcare has become increasingly an information-driven domain, interventions that employ technology are likely to widen access, improve quality and increase service efficiency at a rapid pace. If applied appropriately, they can act as a complementary strategy for strengthening health system performance. Digitalization has facilitated countless advances in several low-and-middle-income countries (LMIC). As a first step, this exercise was conducted to synthesize evidence worldwide with the aims to provide an overview of application of ICT in health also known as "e-health" in low-resource settings within relevant health system building blocks over the past two decades and to identify the facilitators to e-health implementation in such settings. We believe that lessons learnt from this evidence-base are important in developing framework for Bihar's own comprehensive e-health strategies.

Methods

In this review, e-health was defined (as recommended by WHO) as services and information delivered though internet or related technologies to improve health. Scalable implementation of e-health projects in developing countries were searched in electronic databases between 2000 and 2017. Primary research of any design, systematic reviews, grey literature that described successful uptake of a proven IT intervention and published in English language were included for this review. Several electronic databases for example Pubmed, Google Scholar, Embase, Cochrane, Science Direct and WHO website were searched for relevant published literature using appropriate search terms "e health", "information technology", "information and communication technology", "m health", "mobile health", "telehealth", "telemedicine", "e learning", "web-based application", "health technology", "e governance" AND "developing country" OR "low income

country" OR "resource-limited" OR "resource constraint". Endnote X7 software was used for reference management.

The number of records identified through database searching and manual scanning of reference list was 2067 and number of records identified through other sources was 370. Therefore, total number of records identified was 2437. After exclusion, out of total 141 records, 66 were included in the final analysis. The reasons for exclusion were some of the records were just editorials, viewpoints, studies not related to e-health, not implemented or evaluated e-health projects, still in pilot phase and feasibility studies.

Findings

Literature review found that most of these innovative approaches were reported from African countries followed by Asian countries (India, China, Bangladesh, Pakistan, Philippines, Indonesia, Vietnam, Thailand, Cambodia, Malaysia and Myanmar) and South America (Brazil, Peru). Among Asian countries, India was the pre-dominant country reporting appropriate use of technology in the health sector. Interestingly, several e-health initiatives were reported from countries experiencing critical shortage of skilled professionals.

Of the 66 digital innovations included, 24 originated in Sub-Saharan Africa[13-32], 22 from India[13, 14, 32-57], 3 in China[13, 58, 59], 2 each in Peru[13, 60] and Bangladesh[13, 61] and 1 each in Philippines[60], Punjab-Pakistan[62], Thailand[63], Brazil[13], Belize [13], Indonesia[13], Vietnam[13], Cambodia[10] and Myanmar[64]. In India, successful e-health projects reported mostly from the Southern states (Andhra Pradesh[34, 65], Tamil Nadu[38, 44, 45, 66] and Kerala[32, 35]) followed by Gujarat[40, 42, 67, 68], Himachal Pradesh[69], West Bengal[39], Maharashtra[46] and Rajasthan[70]. Majority of innovations in these LMIC were launched between 2007 and 2017. Use of the Internet was the most common digital platform applied in health sector. Among the six building blocks as recommended by WHO[71], innovations were mostly applied to improve access to correct information followed by improving the coverage of health service delivery. Very few reported successful use of technology in human resource for health, supply chain management and health financing. Generation, integration and clear flow of health data across all four levels (individual, facility, community and national) through a robust data collection platform with minimum disruption to the existing workflow facilitated better performance of the health system. Access to real-time information led to real-time monitoring of the health system performance, immediate action and tangible benefits. Several sub-domains of ICT had been tried in such settings which included electronic health records, mobile health, e-learning, telehealth including telemedicine and computer network which are described below:

An electronic record of an individual health-related information in digital form or electronic medical record helped in tracking, treatment and monitoring of patients even in remote areas without internet or slow dial-up connection. Such digitalization of the health system minimized errors stemming from hand-written documents. It established uniformity in data collection process, and increased access to patient-related information. Use of such app helped in easy prediction of logistic requirement well in advance. Kenya was the first country to try Open Source EMR in 2001 for comprehensive ambulatory HIV/AIDS care[28]. This real-time data from all anti-retroviral therapy (ART) centres facilitated uniformity in data collection, effective monitoring and provision of quality care to HIV-positive patients leading to an overall reduction in HIV incidence and multi-drug resistant cases. Similarly, Thailand used this platform for data storing, retrieving and sharing patient records in rural hospitals way back in 2002[63, 72]. It resulted in reduced workload for hospital staff and improved quality of health care services. China also reported similar approach to strengthen health system performance during 2012[58]. In Peru, a web-based medical record system was launched to support and manage Tuberculosis patients in 2001[60, 73]. Following successful implementation of the app, the same tool was adopted in three other countries namely Haiti, Rwanda and Philippines to support HIV/AIDS patients with some modifications- addition of offline component in Haiti[30], Open MRS platform with data dictionary concept in Rwanda [29]and flexible configuration that allowed switching between systems in Philippines[60].

Mobile technology became the most appropriate and adaptable tool for real-time data collection. It includes use of mobile devices such as mobile phones, patient monitoring devices, personal digital assistants (PDAs) and other wireless devices in medical and public health practice [74, 75]. It became very popular because of low cost and ease of use. Use of light-weight handheld computers allows flexibility and mobility in real-time data collection from the field. It is also reliable and less time consuming compared to traditional paper-based household surveys and can be applied by people with little education. Many countries reported use of this mobile app for improving access to health-related information and services. For example, a cloud- and android-based virtual vaccine record platform was developed to increase the coverage of childhood immunization in Bangladesh during 2013[76]. In India, an audio-based mobile service platform was initiated in 2016 to provide weekly health messages (72 audio-messages) during pregnancy by dialling to a toll-free number. In rural Tanzania, a SMS management tool and web-based reporting tool was developed to improve the supply of life-saving anti-malarial drugs between 2009 and 2010[31]. To facilitate communication between community health workers and health system on key maternal, neonatal and child health indicators, a mobile-based app "RapidSMS" was developed in Rwanda during 2009[77]. In Ghana, "MOTECH", Mobile Technology for Community Health, was developed to provide information on safe

motherhood during pregnancy through SMS while Nurses App helped to record and track the care provided to women and new-borns in rural health facilities. In India, a case-based web-based Tuberculosis case reporting system through SMS technology was initiated to facilitate information at different levels of health care system, India "Nikshay", which successfully controlled the emergence of drug resistant cases[78, 79]. Access to real-time data through different apps using mobile technology in combination of the Internet increased birth registration, improved coverage of essential maternal, neonatal and child health services, control epidemic of drug-resistant cases of Malaria, Tuberculosis and HIV/TB.

Given ineffective health care delivery, limited resources including trained medical doctors, poor IT infra-structure, telemedicine may be one of the effective solutions for health service delivery. It became a unique method of health care provision from distant for people living in remote areas. It emerged as a life-saving public health intervention in case of emergency situations and management of critical cases. First successful opensource telemedicine project, "Kgonafalo" was reported from Botswana in 2010[19]. India also became pioneer in providing health care through telemedicine in some of the remotest areas in collaboration with the Department of Space (ISRO), National Rural Telemedicine Network during 2007[36, 80]. Successful implementation of telehealth including telemedicine showed a significant positive impact on health care delivery. Other advantages included substantial reduction in referral costs, improved patient health outcomes and enhanced knowledge of health care providers.

The Internet emerged as a popular digital real-time data sharing platform in many poor countries. Use of computers, networking and other devices help to generate, process and exchange all forms of electronic data related to health in many poor countries worldwide. The National Health Information System (HIS) in Belize and Latin America became the most successful project in the world[81]. India's National Rural Health Mission became the world's largest implementer of Open MRS Health Information platform. Another free and open source flexible health management data platform, District Health Information Software, dhis2, was developed to manage statistical data, transactional data and personal information related to health around 2005-06[82, 83]. In India, the dhis - platform was first implemented in Kerala in 2006. Mother and child name based tracking information management platform, "E-Mamta", at grass-root level was developed to ensure complete delivery of maternal and child health services in Gujarat during 2010[84]. Later it was adopted in Rajasthan and Uttar Pradesh. Through a web-based supply chain management system, "Aushadi SCM System", procurement, storage and distribution of quality drugs became more transparent in Maharashtra during 2013[85]. Other successful e-health initiatives developed for human resource management were reported from Rajasthan (ASHA Soft, service-based online payment and monitoring system for ASHA workers,

2014) [70]and web-based application tool for Human Resource Management in Himachal Pradesh (e-HMRS, Manav Sampada) in 2010[69]. A comprehensive integrated state-level data repository was launched for all tertiary, secondary and primary healthcare facilities to assess overall performance, "State Health Data Resource Center", in Tamil Nadu during 2014.

Application of ICT helped in rational use of health data for evidence based policy and decision making by stakeholders, increased transparency in health data, easy distribution of logistics in poor-performing districts, quick identification of disease trends and scope for improvements and revolutionized drug procurement system (efficient stock management, ensure uninterrupted drug flow, reduced overstocking and wastage), increased transparency in payment process for frontline workers (ASHA). Other benefits included identification of performance levels of frontline workers (ASHA) with subsequent increase in follow-up visits, increased coverage of childhood immunization and facilitated micro-level manpower planning at all levels.

e-learning became another popular method of enhancing staff competencies and capacity. It helped in faster delivery of training sessions and increased reach in prior inaccessible areas. Some of the successful e-learning reported from poor resource settings were- "Akshaya", Kerala, 2002, where at least one person per family had to be e-literate through computer training in the local area[86], "Mobile Senegal' was the first initiative to build capacity in mobile technology by introducing mobile courses in academic institutes in Senegal during 2008[87].

Discussion

There are several successful implementations of digital innovations in health which can be easily adopted in Bihar. For example, as observed in Sub-Saharan Africa and Bangladesh, childhood malnutrition can be reduced by generating real-time data through a central web- and SMS-based data collection platform on key maternal and child-health indicators. This real-time information can be utilized to identify areas with high burden of malnutrition so that delivery of community-based essential services can be enhanced in a timely manner. Taking example from Tanzania, family planning practices can be improved by imparting knowledge through an automated, real-time, interactive and on-demand short message service platform. Peru, Brazil and Haiti showed how access to real-time patient-centred records at the point of care through the internet and electronic medical record can successfully control multidrug resistant Tuberculosis or any other communicable disease even in remote and inaccessible areas. A web-based Hospital Management and Information System using a District Health Information System version 2 can streamline the operations and improve the efficiency of the public hospitals by

providing real-time quality data on patient influx, treatment, human resources, inventory as reported in Myanmar and Gujarat, India. Internet and mobile technologies can be applied to improve health care utilization through "online" health service delivery as implemented in China. Tele-health including tele-medicine can be an alternative virtual platform to deliver quality services particularly in rural areas where access to hospitals are lacking. Human resource being one of the principal health system inputs, workforce management through a web-based app and e-service book can increase transparency, facilitate microlevel manpower planning and reduce inequalities as reported from Himachal Pradesh, India.

These projects as reported in this review became successful despite experiencing several public challenges. Some of such challenges identified were underlying poor health status of the population (high burden of maternal, neonatal and infant mortality, dual burden of communicable and non-communicable diseases), inadequate hygiene and sanitation, poverty, low literacy, poor IT infra-structure (no high-end computer, slow or no connectivity, frequent power cuts and lack of technical expertise), financial crisis and complex and disintegrated health system. Some of the key lessons learnt during this exercise are that if a system does not work manually, technology is unlikely to help. Instead of discarding the existing data, exploring them as much as possible is unlikely to impose a burden of new data collection on already over-stretched health system. Keeping the app simple will encourage better acceptance among end users. Smaller systems might work better than a single big system and use of unified codes for conveying messages will enhance compatibility of the innovations. Another important learning for sustenance of any these successful approaches was rigorous monitoring, evaluation, periodic training and necessary feedback from end users.

However, still there were many perceived threat to sustainability identified across the published data base. One of the most important barriers to digital platform is the general resistance to shift to new system and more so if the system is complex. Other issues related were cost related to service and maintenance, shortage of trained manpower, lack of supporting infra-structure and standard protocols and issues with data security.

Conclusion and way forward

Given health systems are highly complex, there is no single set of best practices that can be adopted as an ideal model for improved performance in other settings. The success of one approach is determined by the underlying characteristics of the health system, local values and ideologies, all these supported by an enabling environment. The urge to use technology without proper identification of the priority health issues often led to frustrating failure. Therefore, before attempting to embed ICT into routine healthcare, it is

essential to ensure that it meets real needs and provides clear value. Thus, it appears that there remains an appreciable need for conducting primary research on technology in Bihar and consequent implementation of the learning to ensure that through efficient technology-based collection, management, analysis and visualization of granular data in real time gets utilized into data-driven evidence-based policy-making and program management so that public health service delivery can be reinforced through an organically developed platform.

Some of the ICT initiatives that reported from Bihar over the past decade were Health Management Information System (HMIS, 2008), District Health Information System-2 (dhis-2, 2008), Mother-to-Child-tracking System (MCTS, 2011), Human Resource Information System (HRIS, 2012), Sanjivani Report Portal for online OPD registration and drug distribution system (2014), Rashtriya Bal Swasthya Karyakram (RBSK portal, 2014) and Supportive Supervision Portal (SSP, 2015). However, published literature on the current status of these projects are limited. Therefore, primary research to know in detail the existing ICT landscape will help to identify the potential facilitators and barriers to implementation of prior e-health initiatives. There is also a need to conduct feasibility study to see how a new ICT app could be integrated into the existing health system to solve the identified priority areas in health sector. Involvement of diverse stakeholders for sharing responsibilities and financial support is an essential first step towards such digital revolution. Partnerships between Academic Institutes, Development partners and Government sector including technology unit to facilitate development of software and training of non-IT volunteers are also crucial. Creating community awareness through workshops is essential to overcome general resistance among people in using newer devices.

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The Centre for Health Policy (CHP) at the Asian Development Research Institute (ADRI) has been set up with support from the Bill & Melinda Gates Foundation to strengthen the health sector in Bihar with a multidimensional and multi-disciplinary approach. Its aim is to engage in rigorous analysis of the health system and inform policy makers to fine-tune interventions for even stronger outcomes.

- Research and Analytical Studies

  It constitutes the core of CHP's activities. The areas of research include health infrastructure and delivery with emphasis on equity, health outcomes such as IMR, MMR, TFR and its predictors, health financing, private-public partnerships, regulatory framework and its implementation, and other issues which might emerge.

- Informing Policymakers on Strengthening the Existing Health System

  CHP aims to be the trusted partner of the state Government in providing evidence-based inputs in making the health system stronger, resilient and equitable.

- Sustainable Health Solutions

  CHP recognizes the need for establishing a strong health system which will be self-sustaining. It means immunity to natural disasters/calamities, financial uncertainties and other unanticipated factors. These pillars may be interrelated; CHP will provide a framework of synergy among actors working on these pillars.

- Collaboration

  CHP engages in collaboration with an extensive network of academic and policy research institutions both in India and abroad in health and the broader social sciences.