Micro Health Centre (µHC)
A Cloud enabled Healthcare Infrastructure

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Abstract. India's achievements in the field of health have been less than satisfactory and the healthcare delivery at the village level is constrained by lack of healthcare infrastructure, lack of doctors, lack of supply-chain and lack of appropriate monitoring of the existing healthcare infrastructure. This paper describes an innovative and low cost health care infrastructure that can be rapidly rolled out to provide basic healthcare using tele health services. It consists of a standard shipping container converted to a Micro Health Centre (referred to as µHC). It is connected to medical personnel through Internet, to bring much needed preliminary healthcare to those in need and provisions for medical equipments being directly linked to the µHC health cloud. The objective is to equip the Micro Health Centre with basic diagnostic equipments that can be operated by paramedics or interns, along with specialist medical personnel providing expert interventions through remote medical consultation. It can have a network connectivity varying from 256 KBPA (via satellite) to 2 MBPS (via leased line). Furthermore it can be easily transported to remote rural areas as all supply-chains such as trucks, trains, roadways etc are aligned to handling shipping containers. The solution has been rolled out in North India on a research basis. As this healthcare infrastructural solution is easy to transport and rapidly deployable thus it is well suited for war torn areas as well as areas affected by natural disasters.

Keywords. Healthcare, Telemedicine, health care infrastructure, health centre, Primary Health Care

Introduction

Commission on Macroeconomics and Health of the World Health Organization (2001) has stated that good health care delivery system is essential for improving health of the masses as well as the economic growth in developing countries[1]. The progress towards achieving the Millennium development goals has been slow and it has been recognized that improvement in healthcare is central towards their achievement[2-4]. There is an increasing consensus that stronger health systems are essential for

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achieving improved health outcomes, this has been the motivation behind the Micro Health Centre initiative[3-6]. The studies done in relation to progress towards achieving maternal and reproductive health suggest that dysfunctional health systems are failing to save women's lives and are unable to meet their healthcare needs[7-9]. In developing nations the health care delivery at village level is constrained by lack of healthcare infrastructure, lack of doctors, lack of supply-chain and lack of appropriate monitoring of the existing healthcare infrastructure[10]. The aim of the Micro health centre is to mitigate the ground-level issues of healthcare delivery to remote areas in India and in other economies that are challenged by the inadequacy of health infrastructure. The µHC aims to provide primary, preventive and promotive care and to act as a referral unit. It is able to deliver the above by providing a cloud-enabled health infrastructure. This infrastructure can enable rural citizens to access specialist medical consultation and provide support for disease surveillance by tracking disease patterns and risk factors. The medical equipments in the µHC are linked to health cloud directly thus no human intervention is required for data collection. Given that µHC is a rapidly deployable infrastructure, it is also appropriate to support disaster relief operations.

The cloud connected µHC can act as a means of performing efficient collection, storage and analysis of patient data, to provide accurate reporting of health indicators and assessing unmet health care needs of the community, thereby ensuring delivery of quality health services and also acting as a tool for creating public awareness. The µHC can be managed by two medical personnel or paramedics for providing care as well as health education and performing simple diagnostic tests.

1. Literature Review

Primary health care has been a vital strategy that remains the backbone of health service delivery in India[35]. It has been recognized that many of the health conditions can actually be prevented at this level by implementing primary prevention and promotion measures before they manifest or progress to a higher degree of illness[36, 37]. It has been observed that the existing physical infrastructure in Primary Health Centres and the number of existing public health facilities need to be enhanced to meet the health care demands in large remote areas of India. The studies by Reddy et al highlights that there is a need to strengthen the public health system as the primary provider of promotive, preventive and curative health services in India[40,41]. In addition, it has been increasingly realized that "Cloud technology" has the potential to provide quality healthcare especially in remote, underserved areas of the population. There are a number of studies reporting the potential benefits of using cloud computing in healthcare and they also propose different models and frameworks[42]. A study by Padhy[43] discusses the design and implementation of a Cloud based Rural Healthcare Information System Model. Several articles, forums, and blogs have reported the successful applications of cloud computing in industry, business, transportation, education, and national security[44-47]. These studies describe the applicability cloud technology for healthcare infrastructure. Also they explore and guide about the cloud computing paradigm to share electronic heath records and address the related security concerns. According to a previous literature review done by Panir in 2011 in relation to the role of ICTs (Information Communication Technology) in the health sector in developing countries it has been suggested that for implementing ehealth as a digital

strategy to non-digital people an integrated, pragmatic and visionary approach is highly important[48].

2. Rationale behind the Micro Health Centre solution

The purpose of this paper is to describe the conceptualization of an efficient solution for mitigating the challenges faced by the Indian Healthcare delivery system. The issues and challenges faced by the healthcare delivery system in India are understood by means of research on the existing published literature in this field. It describes the deployment of the prototype solution in collaboration with Government of India. In India the Government initiatives in public health have recorded some noteworthy successes over time, however the Indian health system is ranked 118 among 191 of the WHO member countries on overall health performance[12]. There are around 741 million rural people in India (72% of the total population, source: Census of India, 2001)[13] and the Tendulkar Committee report states that 42 percent of rural people in India are below the poverty line[14]. Thus it is clear that the current healthcare demands are not being met despite having centers of excellence in healthcare delivery[15]. It is seen that most of the poor people living in remote areas are not able to access formal health care and many of them consult untrained local 'private practitioners' incase of any illness[16]. There is an infrastructure deficit in rural areas[17, 18] and nearly one million Indians die every year due to inadequate healthcare facilities and 700 million people have no access to specialist care[17]. About 75% of health care infrastructure, medical manpower and other health resources are concentrated in the cities or towns where only 27% of the population resides. Contagious, infectious waterborne diseases and reproductive tract infections dominate the morbidity pattern, especially in rural areas[18, 19]. Moreover, non-communicable diseases such as Tuberculosis are also on the rise. A study by John TJ suggests that majority of the rural deaths are preventable[18, 20] and as per the WHO Report 2006 on Global Tuberculosis Control, the major barrier to the treatment of diseases like tuberculosis is the lack of awareness amongst the rural population regarding the importance of the simple methods of treatment[21].

IMR (Infant Mortality Rate) & MMR (Maternal Mortality Rate) situation in India is poor (Black; Hogan) [22, 23]. Shortages in human resources, poorly trained providers, poor quality of care, lack of drugs, contraceptives, supplies, and equipment; and ineffective referral systems are responsible for the lack of progress in reducing maternal mortality and in providing basic reproductive and maternal health services[7-9]. The problems in remote inaccessible areas such as hilly states, north eastern states, desert areas and tribal areas are more acute due to shortage of human resources including medical and paramedical personnel. Moreover, rural public health facilities have a difficult time attracting, retaining and ensuring regular presence of highly trained medical professionals[25].

Another focus of research in recent times has been the degree of absenteeism among health providers (Banerjee; Choudhury) [26, 27]. The primary reason for absenteeism appears to be the quality of infrastructure at the facility[27], also the supply systems for essential drugs, equipments and diagnostic services in public health departments have been weak and in the year 2007-08, only 65·3% of subcentres and

69·6% of primary health centres were thought to have adequate supplies (≥60% of essential drugs) [28-30]. Data management is difficult in the currently existing manual system which leads to duplication of efforts and wastage of time (Krishnan; Siriginidi) [31, 32]. Lucus and Peters report that efficient data management using Information Technology is essential for quality assurance and cost effectiveness in delivery of care [33, 34]. These findings were the source of motivation behind envisioning of the Micro Health Centre as a rapidly deployable infrastructural solution for healthcare delivery.

2.1. Key issues that limit the delivery of basic healthcare

The research done on the existing published literature regarding the issues and challenges in healthcare delivery in India reveals that although a well defined system of public healthcare provision exists in India still there are some shortfalls, as identified in this paper such as:
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- Physical infrastructure deficit in rural areas and lack of monitoring of available healthcare infrastructure
- Lack of adequately trained staff as well as lack of monitoring of the staff
- Lack of adequate access to the existing facilities
- Lack of medicine and other basic supplies and inadequately functioning equipment
- Poor maternal and child health services, poor disease management services for both communicable and non communicable diseases
- Manual data collection leading to inefficient/incorrect data management

2.2. Conceptualization of the µHC solution

A careful review was done of the published literature on the issues and challenges faced by the healthcare delivery system in India. Primary health care and its role and the importance of informatics in healthcare delivery in resource constrained settings were studied. The literature search was done to generate peer-reviewed academic articles. For this purpose, several databases such as SpringerLink, PubMed and Sage journals online were utilized. The review was supplemented by other e-journal search engines including 'Medline' and 'Google Scholar'. The search was carried during the period December 2011 – January 2012. A total of eighty articles and abstracts were reviewed for their relevance for this study. The literature review done is qualitative and based on performing iterations and revisions of the material, until a consensus interpretation was achieved[11].

This research facilitated the conceptualization of an innovative solution addressing the key challenges of Indian healthcare delivery system in the form of the Micro Health Centre solution. This solution is based on the application of information technology for improving healthcare delivery. The solution aims to overcome the challenges of Indian healthcare by providing primary healthcare and tele-health services, thereby strengthening the Indian healthcare delivery system. The conceptual framework presented below has been developed by the authors and utilized for the purpose of this study. The framework consists of studying the existing research which is done on the issues and challenges in healthcare provision in India. As a result of this study the

issues that limit the delivery of basic healthcare were identified and then collated. The next step was the conceptualization of an innovative and implementable solution for mitigating the identified key issues. Then collaborative work was undertaken with the Government of India to create a prototype of the solution. This solution has been rolled out in North India's Haryana region on a research basis.
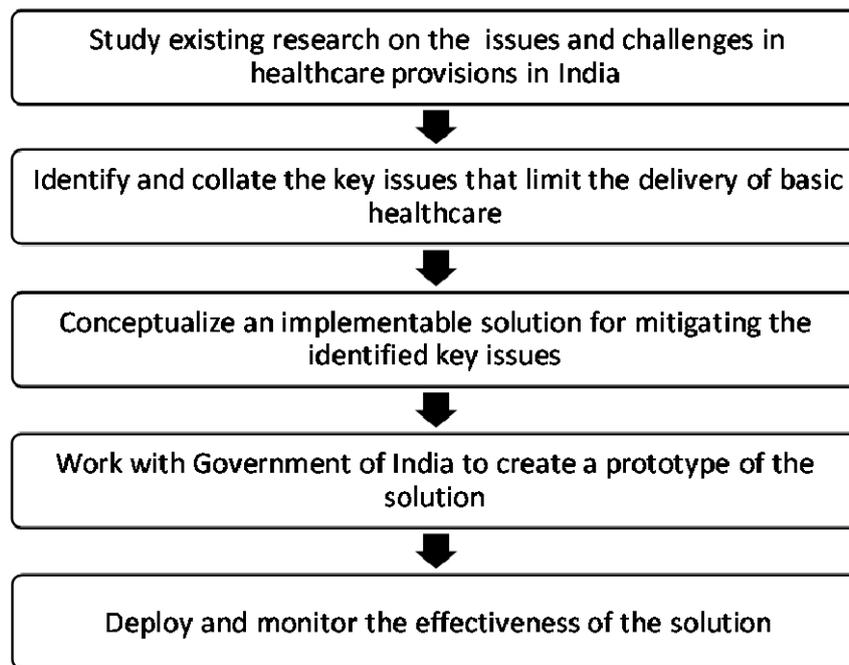

Figure 1. The above Conceptual framework was developed and utilized for the purpose of this study and this framework led to the conceptualization of the innovative and rapidly deployable Cloud Enabled Micro Health Centre solution

2.3. Micro Health Centre - solution for mitigating the identified key issues

Keeping the above in mind, a rapidly deployable self sustainable infrastructure, backed by robust healthcare services accessible from anywhere, at any time, to the common man has been conceptualized. The Cloud connected Micro health centre solution conceptualized for Indian healthcare needs aims to provide access to basic, equitable health care for well being of the rural population and within their easy reach thereby meeting the severe inadequacy of health facilities in such places. The objective is to equip a health centre with basic diagnostic equipment that can be operated by paramedics or interns, with specialist medical personnel providing expert interventions through telemedicine. It is based upon the finding that in resource constrained settings Telemedicine applications may serve as the only means to reliably obtain healthcare[49-51]. The solution is equipped with built in electricity through power generators, built in connectivity, telemedicine services and it requires minimal training to operate. It aims to provide access to right treatment and early information to people in inaccessible remote areas.

3. Components of the Micro Health Centre solution

There are three components of this healthcare solution: 1.) The Cloud enabled Physical Intelligent Healthcare Infrastructure, 2.) the remote Health Studio at a medical college or hospital, and 3.) the Health Cloud. These are further elaborated below.

3.1. The Cloud enabled Physical Intelligent Healthcare Infrastructure

A standard shipping container is converted into an intelligent Telemedicine Health Centre, designed to meet the local needs and conditions without any infrastructural constraints. The infrastructure at the µHC consists of a registration area with data entry facility and waiting area, two telemedicine studios, daycare area with two inpatient beds, minor OT for carrying out patient dressings, laboratory area, pharmacy and general store area. It aims to address basic health issues and deliver preventive healthcare such as immunization. The Micro health centre design is fully insulated, having good ventilation and electric lighting. It also includes furniture, electrical wiring, plumbing and minimal lab facilities.
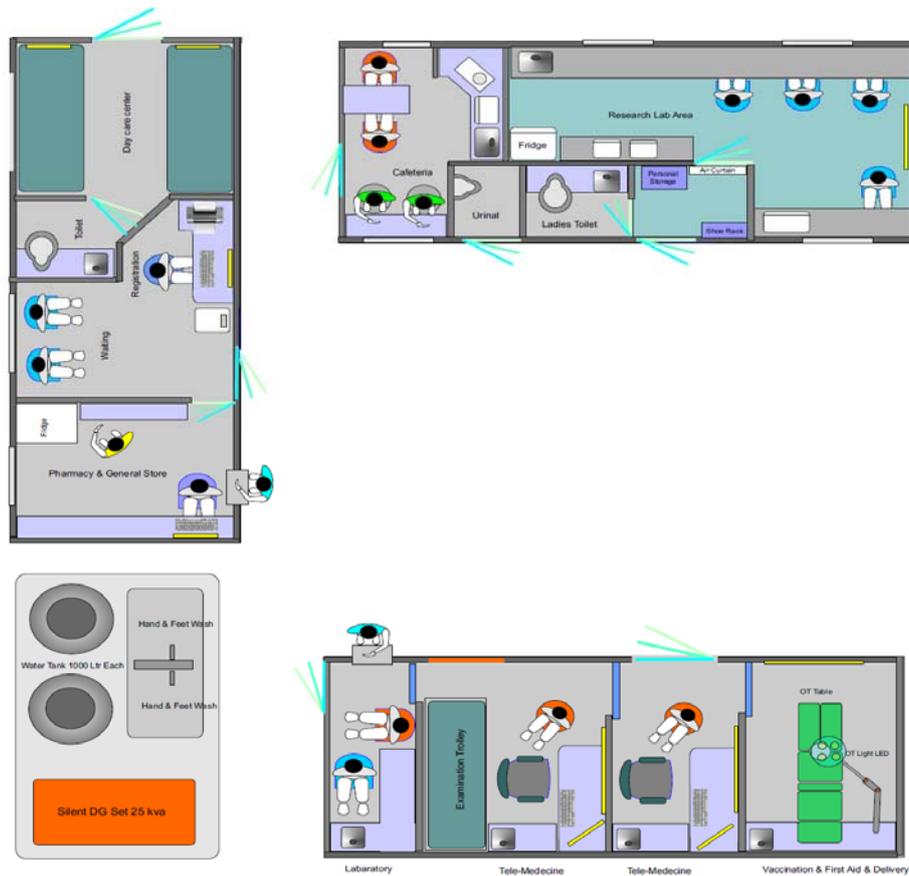
Figure2. Layout of the Micro Health Centre.

3.2. The remote Health Studio at a medical college or hospital

The Micro Health Centre can provide telemedicine consultation to patients in remote rural areas and also referral services to patients requiring specialist medical care. It can provide easy access to consultation from expert doctors through telemedicine facility at the affordable cost of primary healthcare. It provides availability of enhanced quality and timely medical services and can avoid unnecessary travel for health care needs. The μHC can increase the reach of healthcare and can lead to improved communications between healthcare providers separated by distance through tele-consultation and video conferencing.

3.3. The Micro Health Centre Cloud

It aims upon harnessing cloud technology through a Health cloud set up by Hewlett Packard India for providing specialist medical care to remote areas, to aid in disease surveillance by tracking disease patterns and risk factors, disaster management and a means of providing efficient collection, storage and analysis of patient data. The remote monitoring of functioning of the µHC and its equipment through transducers can be done through health cloud and can lead to improved patient care.

The patient's medical history and a record of every consultation will be stored in the web based electronic medical records, thus building up a patient database for future reference. The Electronic Medical Records being used for this initiative is openEMR, which is a free and open source solution. The openEMR solution was chosen based upon its easy customization and wide acceptance by the medical community. The health database thus generated by the EMR system will serve the following purposes – improved monitoring, supervision and quality of service delivery, better data storage and management, disease surveillance and assessing the unmet health care needs of the community. The health cloud will provide the capability to link the output of the diagnostic instruments with the central medical node. It will be the first solution in India having biomedical device integration with the health Cloud and will be helpful in analyzing the equipment usage by the healthcare personnel at the µHC. The data collected will be invaluable for research purposes by providing information regarding health indicators such as infant mortality rate, maternal mortality rate, death rate, causes of deaths and patterns of diseases and injury. The main benefit is the elimination of manual data collection and the possibility of typing errors. Training and awareness regarding healthcare can be provided through telecommunications to patients and healthcare providers. The centralized health database can be used for sending of automated reminders of vaccination and TB drug administration, as well as tracking patient dropouts from the immunization programmes.
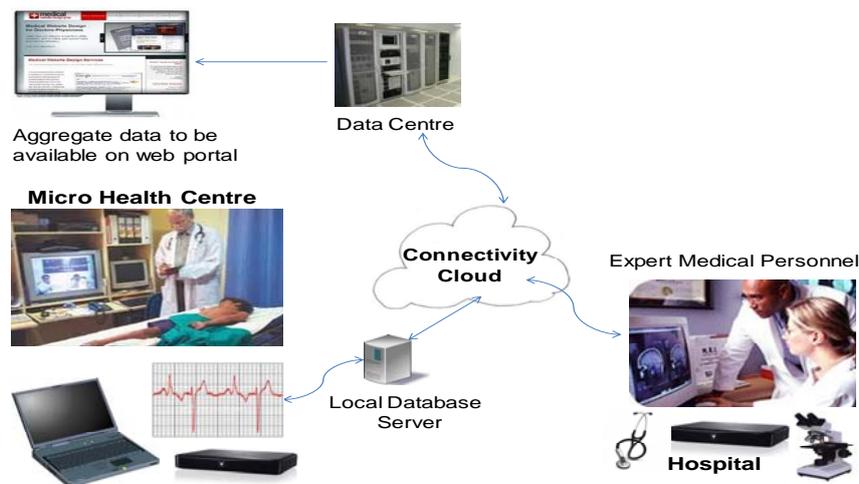
Figure 3. The Cloud connected Micro Health Centre

Figure 4. Micro Health Centre – Electronic Health Records

4. Operations and services offered

Simplistic training in computer usage and online health records maintenance is sufficient for the medical interns positioned at the Micro Health Centre. These medical personnel perform data collection, provide primary care to patients, provide telehealth services and perform basic diagnostic tests.
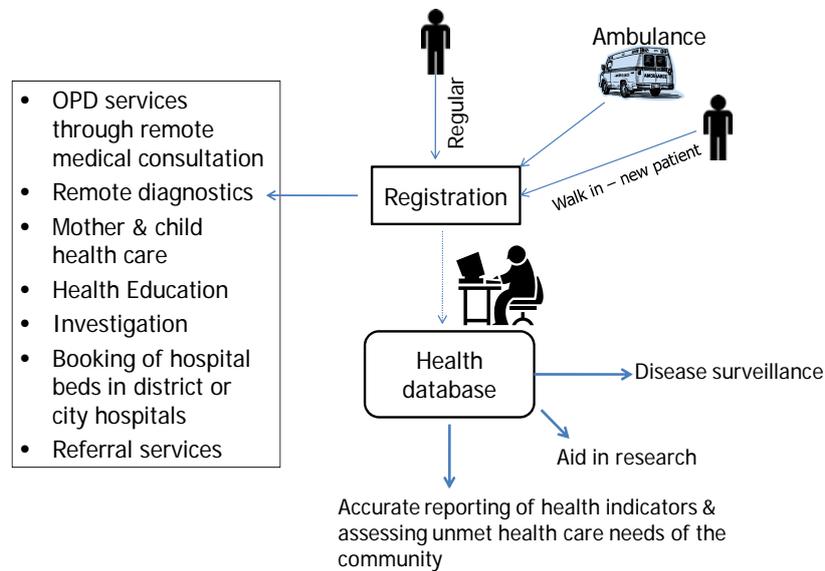
- OPD services through remote medical consultation
- Remote diagnostics
- Mother & child health care
- Health Education
- Investigation
- Booking of hospital beds in district or city hospitals
- Referral services

Regular

Ambulance

Registration

Walk in – new patient

Health database

Disease surveillance

Aid in research

Accurate reporting of health indicators & assessing unmet health care needs of the community

Figure 5. The operations of the Micro Health Centre.

The µHC is provides following services:

- Delivering primary, promotive and preventive healthcare
- OPD services
- Tele health services: real-time support to physicians, tele-consultation, information dissemination, research, video conferencing
- Availability of essential drugs
- Mother and Child healthcare services including immunization and family planning services
- Referral services
- In-patient services
- Education about prevention and control of locally endemic diseases
- Health Education and Behavior Change Communication (BCC)
- Laboratory services such as all general tests, including blood and sputum tests.
- Record of Vital Events and Reporting
- Disease screening for Diabetes, Hypertension and COPD (chronic obstructive pulmonary disease)

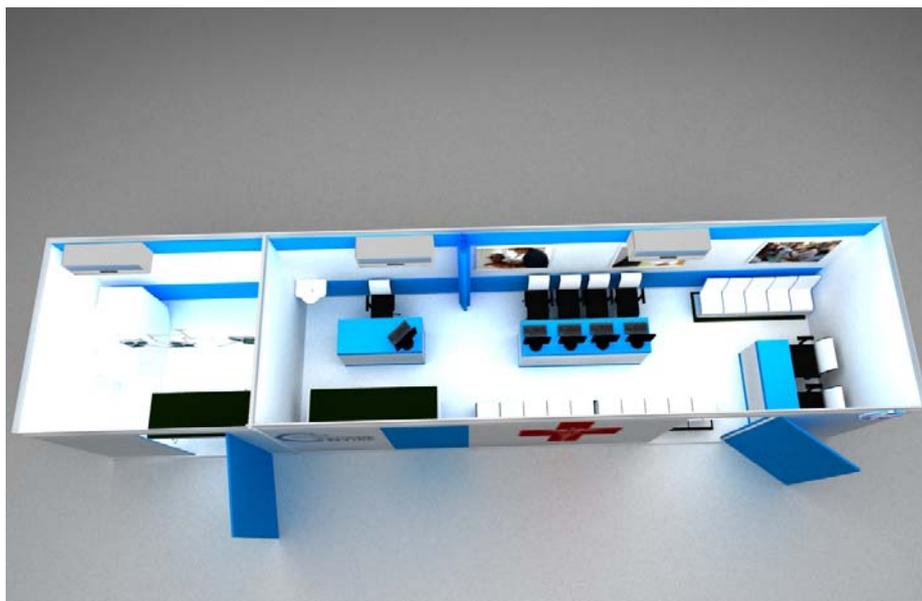**Figure 6 a.** Micro Health centre structure.

Figure 6 b. Micro Health Centre layout.

5. The importance of this solution for other developing countries

Due of the lack of healthcare infrastructure, developing countries suffer disproportionately from diseases and other public health problems. It is seen that three out of eight United Nations Millennium Development Goals aim to enhance healthcare for large sections of the population[52, 53]. These goals can only be achieved by developing healthcare infrastructure on a sustainable basis. The Micro Health Centre solution can start functioning from the first day of its deployment, thus it does not need a high set up time and can rapidly achieve disease management in the developing nations.

The μHC solution can have far reaching benefits for disaster affected regions and can help in coping with the crucial insufficiency of medical resources in these regions. In case of a disaster, most of the terrestrial communication links either do not work properly or get damaged. In such a situation, leveraging on the health cloud technology and satellite connectivity can be an ideal solution. Moreover being set up in a shipping container the μHC is a suitable infrastructure in case of earthquakes, famines, hurricanes and for flood prone regions. In these situations a lot of data has to be collected during the treatment and the injuries need special medical support. The use of health cloud technology can help to cope with these scenarios. In the terrorist affected regions and war prone regions, the μHC infrastructure can assure the delivery of high quality healthcare. In the μHC, devices like ECG monitoring, glucometers, stethoscopes and even ophtalmoscopes and otoscopes can be attached to videoconferencing equipment and by means of the tele-video medical technology simultaneous examination and monitoring of a telepatient can be done, thus leveraging upon cloud computing for healthcare delivery. Also it can serve for the post traumatic healthcare needs where mental health needs are most pressing and local mental health resources are often very limited. Similarly, in remote inaccessible areas such as hilly terrains, this infrastructural solution can be easily deployed as it can be transported by means of air transportation system and tele health services can be provisioned by means of cloud computing[54, 55].

6. Conclusion and future perspectives

The μHC presents an innovative healthcare infrastructural solution. It ensures delivery of high quality health care. It aims to provide essential health care services with Health Cloud connectivity, thus providing invaluable data for research and health policy planning. The advantage of the μHC is that the existing shipping containers are used as base, enabling ease of deployment at any location any time, since all supply-chains such as trucks, trains, roadways etc are aligned to handling shipping containers. As a result it can be transported easily to remote inaccessible areas. The solution is also valuable for urban areas where the concept of family physician is fast disappearing[57, 58] and very often the first point of healthcare services in urban areas is now the hospital infrastructure. This not only makes basic healthcare expensive, but also puts pressure

on an already overloaded healthcare system[59, 60]. This solution also has the potential to provide healthcare to the poor in developed countries by leveraging the low cost health infrastructure of developing countries. The μHC has the potential to make a difference in the lives of many people as it has the ability to rapidly become functional. The healthcare delivery at the Micro Health Centre can be monitored through cloud computing, thereby providing highly efficient and quality healthcare. In future, the Micro Health centre solution can be integrated with tertiary care centres for telemedicine consultations and referral of patients. Centralized health records will further aid in provisioning of health insurance to the masses. Thus it can dramatically increase the reach of healthcare, bridging the Indian healthcare need gap.

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