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Integrating Digital Health for Healthcare Transformation: Conceptual Model of Smart Healthcare for northern Borneo

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ABSTRACT

Digital health has revolutionised the delivery of healthcare globally. However, integrating digital health in the system for transforming healthcare at a larger scale needs to be contextually relevant. Sabah, a state in northern Borneo, has distinctive public health concerns on thalassaemia, colorectal cancer, ischaemic heart disease, mental health, malaria, tuberculosis, and maternal and child health. Envisioning equal access to healthcare throughout the state, a conceptual model called smart healthcare is conceived for healthcare transformation through digital health integration based on the main clinical niche. The three domains of smart healthcare model is smart hospital, smart wellness and smart uber health. Smart hospital is aimed as the central core for materialising smart healthcare model as it serves as the platform to integrate digital health for diagnostic tools and treatment modalities. The purpose of smart wellness is to ensure uninterrupted healthcare and promotes preventive medicine at home and community setting through the ecosystem feeding by the smart hospital. This ecosystem is connected with smart uber health in order to bring the healthcare services to patients and succesfully overcoming the issue on inaccessibility. Each domain is highlighted with certain niche and related healthcare technology.

Key words: digital health, smart healthcare, transforming healthcare, healthcare in sabah

1. INTRODUCTION

The healthcare services in Sabah are governed by the Sabah State Health Department *(Jabatan Kesihatan Negeri Sabah)*. In the past more than 4 decades, Sabah has seen growth in the healthcare development and by 2019, there are more than 340 primary healthcare facilities throughout the state including health clinics, community clinics and dental clinics, with 24 hospitals (both tertiary and district hospitals included). Life expectancy for male and female have risen from 71.8 and 76.3 years in 2006 to 73.9 and 77.6 years respectively. Looking at the maternal, neonatal and infant mortalities, their figures are increasing although two thirds were contributed by immigrants (Table 1).

Table 1: Statistics on mortality rate in Sabah for the year 2006 and 2014 [1]

Parameters (per 1000 population)	2006	2014
Crude birth rate	15.7	16.0
Crude death rate	2.10	0.45
Neonatal mortality rate	5.47	8.47
Infant mortality rate	9.47	12.96
Maternal mortality rate	0.99	0.93

The rate of communicable diseases have reduced in parallel with the socioeconomic improvement of its people, nevertheless, the occurrence of these diseases in Sabah remains high compared to other states in Malaysia [2]. This situation is made worse by the upward numbers of non-communicable diseases (NCD) including cardiovascular diseases, thalassaemia, colorectal cancer and mental health issues up to the point that these diseases further strain the limited health resources available [3], [4]. These public health concerns are further complicated by health inaccessibilities. With wide geographical variation and coverage of 73,631 km², the accessibility of healthcare is a constant struggle for the state hindering adequate healthcare accessibility and fair treatment to the whole state, for instance, advance therapeutic treatment modalities are made available only in the most highly populated area of the state, that is Kota Kinabalu. Despite embarking on logistic services through land, water and air for mobilising healthcare services in the deep rural regions, issue with health inaccessibility remains a priority.

A wider strategy for effective healthcare delivery have to focus in distributing healthcare services to the whole state in order to enhance the quality of preventive, curative and rehabilitative care. For this, health information system is vital to be properly established with appropriate capacity. However, a relevant problem in the low- and middle-income regions including Sabah is inadequacy in the health information systems, highlighting the importance of implementing ICT in the healthcare industry.

Another pertinent point to emphasise is the fact that the healthcare system in Sabah is heavily subsidised by the government that would not be sustainable in the years to come due to the rising cost of healthcare. Concerns with the current public health issues have led to the rising of public awareness and expectations for a more efficient delivery of healthcare. Henceforth, Sabah is in dire needs for an innovative approach in delivering excellent, good quality, affordable and sustainable healthcare services across the state for its people.

Digital health is the emerging new concept seen as the future innovative approach to be adopted for transforming healthcare. Blooming web-based health applications, widely available wearable health monitoring devices, remotely controlled health consultations (e.g. telehealth) and technology-based diagnostic tools have gradually taking over the way healthcare services are delivered. In this state, an examplary of such innovation is the home grown web-based application developed for the notification of birth that has now been adopted by the country's health ministry as standard of practice. Furthermore, with subsidised healthcare services leading to exhaustion of state resources, a cry for a more comprehensive healthcare exclusive for Sabah would be the next agenda.

This article highlights a perspective view on digital health implementation based on dignostics, treatments and promoting wellness, and subsequently presents a conceptual model of smart healthcare as the way of transforming healthcare in Sabah through three main domains: smart hospital, smart wellness and smart uber health. It emphasises on targeting focused clinical niche areas in the state and denotes ways of each domain inter-related with each other.

2. RELEVANT WORKS ON DIGITAL HEALTH

Digital health in the healthcare industry is aimed to provide effective healthcare delivery to patients not only at the hospital setting, but also geared towards patient-centred, personalised healthcare planning by bringing the health and treatment to the patients through the implementation of technologies [5]. Digital health must have the aptitude for seamless integrated data, predictive big data analytics and trustworthy data protection, impying the needs to rely on massive data using cloud services to allow real-time accessibility of patient information at a mass scale. In other words, digital health can be implemented at anytime and anywhere.

Current generation medical devices depend on big data analytics for machine learning in diagnostic and therapeutic purposes. Healthcare facilities in the developed regions have widely adopted digital health concept for promoting wellness in the community to overcome the barrier stemmed from accessibility issue. In the process of keeping up with the rapid growth of new technologies, highest threat that halt the digital health is breech of the patients' personal information and privacy. As such, immense works are required to enhance information safety including research in cybersecurity and encryption.

2.1 Diagnostic tool and therapeutic modalities

In majority of communicable diseases, rapid detection of outbreak is a priority for disease surveilance while early diagnosis is emphasised for potentially debilitating non-communicable diseases. Advancing genetic studies have led to the development of whole genome sequencing for fast and reliable identification of pathogens. Current digitalised era has made it feasible for a real-time whole genome sequencing though central database for worldwide cross-referencing [6]. The internet-based solution means that any isolated pathogens can be easily identified without delay for recognising spatial distribution within short time-frame. Further works are done for enhancing securty with the healthcare cloud that serves as the platform for storing genome sequence [7].

Cardiovascular disease and cancer are leading causes of death, hence early diagnosis is warranted for early intervention. Most of conventional methods applied are labor-intensive, time consuming and cost ineffective. Digitalising medical laboratory through the development of lab-on-a-chip (LoC) technologies in recent years has revolutionised the ways these non-communicable diseases are detected [8]. Cutting edge algorithm for tumour detection from radiographic images such as conducted for lung cancers has the aptitude for better extraction of the region of interest [9]. Signal processing techniques are being developed for detecting coronary heart disease based on human cardiac sounds [10].

2.2 Paradigm shift towards promoting wellness

In order to bring the digital health beyond the hospital setting for global care initiative, the development of healthcare applications and consumer grade tracking devices like smartwatch, in-home mapping of physical activities, eating pattern monitoring, patients adherence to medication are just of the few examples that proved the medium for promoting wellness [11]. There are now systems developed for detecting illness based on the change in behaviour among elderly so that early intervention can be delivered [12]. A larger scale of community-based innovative program for promoting wellness is demonstrated in Japan, called as Smart Wellness City [13]. Here, the concept is to lead happier and better quality life by infrastructuring the transport system and reducing car dependency. Long term assessment is explored through data analytics of the health outcome at population level.

Integrating exercises in the healthcare system as predictive and preventable medicine has become the trend for promoting wellness, not just confined to productive age group but increasingly observed for older people for promoting successful aging. In addition to supported infrastructure and services as suggested by WHO Global Age-Friendly Communities [14], like conducive home residents, affordable logistics and safe outdoor environments for the elderly, monitoring of healthy lifestyle in this population is lacking. Web-based physical activity tracker system for older age group has been developed in low-income countries to be utilised with smartphones as initiatives for remote monitoring that can be reviewed by nearby primary care physicians [15].

3. DESIGN PRINCIPLE

The highlighted examples of digital health stated earlier are merely a small fraction of thousands, if not more of digital health integrated in the healthcare systems among developed and some developing countries. Such advancement appears promising to be implemented as the medium to shift the healthcare system in Sabah, but this requires collaborative effort to ensure that the delivery of healthcare is innovative, sustainable, contextually relevant and accessible throughout the state.

With that views, transforming healthcare through digital health integration can be conceptually modelled as smart healthcare focusing on the relevant clinical niche in this state: thalassaemia, colorectal cancer, tuberculosis, malaria, mental health, ischaemic heart disease, and maternal and child health. This smart healthcare model consists of 3 inter-related domains: smart hospital, smart wellness and smart health uber (Figure 1). Smart hospital is the integral core that acts centrally, not only for health diagnostic and therapeutic purposes, but also as the brain for feeding into an ecosystem that connect with smart wellness and smart health uber domains.

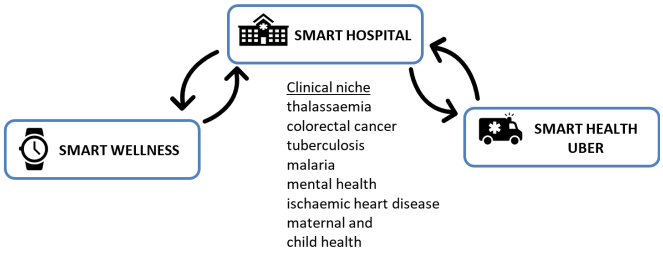

Figure 1: Conceptual Model of Smart Healthcare

4. PROPOSED SMART HEALTHCARE MODEL

4.1 Smart Hospital

A concept of having a smart hospital in Sabah permits patients' information, diagnostic services and algorithmic treatment plans to be available at the tip of the finger with high level of accuracy. This is trivial in the field of health upon dealing with clinical judgement and treatment plans, whether directed for life-threatening, critical episodes or fatal conditions.

Sabah has one of the highest rate of thalassaemia in the world and the life expectancy is improving [3]. Despite tremendous effort on imparting genetic awareness among affected individuals, the rate of thalassaemia continues to rise. Diagnosing the disease is costly and the growing figure of thalassaemia cases implies higher allocation of health burden for thalassaemia-related complications (40% of the state's blood supply in 2018 was catered for this condition). Therefore, the emphasises are not only steered towards cheaper, readily accessible screening tool but have to be concentrated in the direction of aging with thalassaemia. A classifier screening based on datamining from blood test is proven to be beneficial but requires further validation [16]. Presence of an automated screening on nutritional status (e.g. iron levels) and inflammatory markers during regular hospital follow-up using simple form of scanner can be utilised as stratification method to anticipate risk of infections, so that early intervention is delivered avoiding anticipated admission.

Population-based screening for colerectal cancer is aimed to expedite the referral for hospital diagnosis through colonoscopy as gold-standard. Nevertheless, the delay for inititating treatments rooted from the time taken for biopsy results to be available and duration of the staging process. If these slides and images are interpreted automatically, earlier biopsy and staging results can be determined. Increasing number of studies are seen on analysing imaging modalities by augmenting conventional images towards a cutting edge images that can be pooled into a large imaging libraries via massive databases to aid in improving the diagnostic accuracy [17]. This similar, creative digital health solution would be an innovative approach for a smart hospital to adopt as the centre for developing diagnostic imaging, for instance, confirming and monitoring serial chest radiographs of suspected tuberculosis captured in rural areas of the state.

Whole genome sequencing would be the next frontier of genetic study in Sabah and a hospital with smart concept should aim to be the core of a massive, web-based genetic library that is contextually relevant and widely accessible. Thalassaemia and malaria definitely deserve such special attention due to their high prevalences in this state. This

state-of-the-art solution can be seen as an alternative for containing and monitoring outbreaks, specifically for a state with various geographical distributions facing issue to mobilise healthcare team to inaccessible areas.

On top of these, smart hospital serves as the right platform for medical tourism. Sabah is seeing increasing numbers of foreigners and expatriates and majority have medical and insurance coverage. As smart hospital allows seamless data integration, provision of medical care for individuals residing outside Sabah is made plausible, leading to international medical recognition and enhanced sustainability.

4.2 Smart Wellness

As iterated earlier, promoting wellness is to be instigated from home and community. In addition to widely accessible smartphone applications and web-based programs for common conditions like diabetes, hypertension and dyslipidaemia, the population would benefit from digital health solutions that not only aiming for monitoring (e.g. web-based blood pressure trekker or glucose reading), but aspire to focus on self-empowerment and be extended towards preventive measures for complications such as ischaemic heart disease and stroke. Additional concerned areas that worth to dwell in Sabah are mental health and, maternal and child health because the state still seeing mortalities and morbidities in this vulnarable population.

A gamification concept as part of digital health for monitoring individuals with diabetes is a scheme to enhance treatment compliance and disease understanding with objective to foster well-informed individuals for self-management [18] and such concept can be easily adapted to other common non-communicable diseases. Home-based physical actvitiy monitoring is no longer considered as a new health technology but emerging concept of predictive algortihm using this tool is becoming popular. The goal is to analyse an individual's daily activities and predict the likelihood for developing ischemic heart disaase or stroke. Motivational drive behind this notion is to enhance active lifestyle as primary prevention.

Sabah recorded the second highest number of population with mental health illness in the country with depression as the major contributor. Despite the rising rate, the level of awareness remains low, remains underdiagnosed and monitoring treatment compliance is problematic especially for those living in remote areas. Embedding digital health for tackling these issues would not only combat this silent killer but the chance for success is much higher due to smartphone availabilities to all age groups including the elderly. The next step is to develop user-friendly applications and tracking devices for mental health screening and self-management while able to detect harmful acts to oneself.

Health of expecting mothers, unborn babies and very young children has been haunting the health department for years, mainly due to the high mortality and morbidity, although the numbers are reducing. It is mainly contributed by the influx of immigrants and poor compliance to antenatal and medical check-ups. Hence, family planning is imperative and prescribed at low cost, but yet not fully benefitting the population due to healthcare inaccessibility for repeated contraception treatment. Similar matter erupts with schedule of vaccination although dozens of small health clinics are scattered throughout Sabah. A call for comprehensive healthcare database for rural population is in dire need so that monitoring of defaulters can be efficiently conducted for interval healthcare visits.

Despite the presence of various web-based applications and readily available remote sensors, one of the notable problems for implementing smart wellness is the lack of coordination between the digital health technologies developed for community or home based used with the core healthcare system, a.k.a the smart hospital. Different model of feedback system has been proposed, which include ecosystem on healthcare services cloud that is aimed to provide a hosting environment fostering coordinated collaboration of healthcare delivery [19]. Personal data collected can be curated and feed into the healthcare system to further identify areas of concerns that warrants medical attention.[54]

4.3 Smart Health Uber

Originally started from 'Uber' e-hailing service (i.e. ordering transport via smart device), concept of uberisation is now used for 'ordering' various services including healthcare service to the patients. Diverse geographical distributions limit healthcare accessibilities in remote areas of Sabah. There are mobile clinics as part of outreach services in the attempt to resolve inaccessibility issue, but the services are limited by the frequency interval of these clinics, hence the needs to find a better solution to cater for unpredictable health issues. Imagine a patient suffering from a medical emergency, through a click of health uber application, a nearby healthcare professionals team will be alerted to contact the patient or family members thus avoiding complications as a result of delayed therapeutic interventions. Successful healthcare uberisation is heavily influenced by the presence of local health team to mobilise for delivering the health uber service.

Locally appointed medical team is desired at the targeted areas where the health 'e-hailing' service covers, and this team ideally consists at least physician, nurse and pharmacist. There are more than 300 healthcare facilities in the state and each consists of at least physicians (visiting or in-house), nurses and some are well-equipped with ambulance. Hence, such comprehensive manpower can be utilised to materialised the idea of healthcare uberisation. However, potential source

of medicolegal implications from this particular service is rooted from relaying clinical information from the smart hospital to the local medical team. Certain patient's information has to be shared with the tream in order to anticipate, provide and deliver appropriate treatment plan when delivering the healthcare services, examples include pre-morbid medical conditions, prescription information and history of allergies. Data sharing policy in this country is not lengthily established and properly governed like those implemented in the developed regions.

On the contrary, the current practice of submitting referral letters containing patients' demographics and in-depth clinical informations for referrals from any tertiary medical centre to the primary care physicians is considered as an implied informed consent with main objective of ensuring continuity of medical care. Similar referral system is plausible through the uber healthcare application by linking with the smart hospital healthcare system. However, the risk of information leakage cannot be underestimated, which potentially can be overcome by enhanced cybersecurity system.

5. DISCUSSION

Transforming healthcare in Sabah through smart healthcare model focusing on relevant clinical niche areas is an innovative approach to provide equal healthcare services for the whole population. In this model, the smart hospital serves as the central core for feeding the smart healthcare ecosystem and complement the smart wellness and smart health uber. Implementing such healthcare model would undoubtedly revolutionised the healthcare transformation in Sabah but the major hindrance for successful implementation is constrained by interoperability issue. Information leak, medicolegal repercussion and interoperability may hinder implementing this model at a large scale. Also, presence of several agencies as the healthcare providers confer problem to provide unity healthcare services. Collaborative effort from the government as well as the non-government agencies for a more comprehensive health network and information system would permit better infiltration of digital health coverage throughout Sabah, especially for materialising the smart healthcare model. Such hindrance requires experts from the ICT field for finding means to overcome these.

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