Population Health Management Outcomes Obtained Through A Hospital-based And Telehealth Informatics-enabled Telecare Service

Ching-Kuan Liu[1], Chung-Yao Hsu[1], Feng-Yueh Yang[1], Jasmine Wu[2], Kayla Kuo[2], and Por Lai[2]
1, Kaohsiung Medical University Hospital, Kaohsiung Taiwan
2, Crux Health Technologies Co., Ltd., Taiwan

Abstract—**Effective population health management has emerged as an important public policy measure for achieving strategic objectives concerning sustaining budget plans and ensuring competitiveness in the era of an aging society and a pandemic environment. ICT solutions can greatly facilitate achievement of these strategic objectives. In this report, we describe promising outcomes obtained from the use of a hospital-based and telehealth informatics-enabled telecare service model. This 24/7/365 service model features (1) effective integration of health data such as electronic health record, electronic medical record and personal health record, (2) establishment and use of personalized vital sign base lines, (3) design and use of insightful new specific rating scales, and (4) use of well-defined operating procedures for conducting performance in a stringent regulatory environment. Our novel service model has demonstrated its capability to achieve important population health management related strategic goals such as (1) reducing time to access proper medical service, (2) reducing rate of emergency visit, (3) reducing rate of readmission, (4) reducing hospital stay, (5) reducing possible medical errors, and (6) reducing harms caused by possible overuse and/or underuse of medical services. Significant outcome examples in relation to management and prevention of hypertension, stroke and medical error are presented. Potentially, this service model can also be used for evaluation and validation of technological solutions for medicine.**

Index Term—**Population Health Management, P4 Medicine, Telecare, Telehealth, Telehealth Informatics, Triple aim.**

I. Introduction

Population health management (PHM) intends to productively manage the clinical and financial aspects of population health which is defined as the overall health outcomes of a group of individuals [1, 2]. PHM requires technological supports for collection, validation, analysis, warehousing and use of vast health data. PHM also involves formulation and implementation of policies that aim to transform impacting health determinants into improved health outcomes. While health determinants may include clinical practice, health care, individual behavior, social economic status, physical environment, genetics as well as epigenetics, the health outcomes are evaluated by measures of mortality, health related quality of life, and cost-effectiveness. Cost-effectiveness is on the health triple aim agenda [3] as health expenditure has been an increasing budget burden in many countries, in particular, those facing pressure of an aging society.

A recent report estimates that global spending on health will increase from US$9·21 trillion in 2014 to $24·24 trillion in 2040 [4]. Furthermore, the world's major regions are expected to see health care spending increases at a rate of 4.3% (CAGR) between 2015 and 2020 [5], compared to the significantly lower rates of global GDP growth at 3.4% and 3.7%, in 2015 and 2020 respectively, as computed by IMF [6]. Effective use of health resources requires coordinated P4 Medicine (personalized, predictive, preventive and participatory) approaches [7]. In particular, preventive measures have shown great contributions to PHM as indicated in the recent report that observes reductions in incidence of coronary heart disease have come more from reduced exposure to specific risk factors (55%) than from all clinical interventions combined (40%) [8]. Equally important is to ensure the use of right care in achieving population health objectives [9], as both overuse and underuse of medical services are common, universal, and harmful. Despite the fact that both overuse and underuse of medical procedures are harmful, there appears that no single solution will fix the problem.

Technology can greatly contribute to establishing essential capabilities for achieving goals of preventive health. Achieving such goals likely has to rely on building usable health big data, in particular, those relating to personalized and predictive health. In consideration of meeting urgent demands for effective PHM, our service model was intended for building such health big data through the user-centered practice that features adoption of technology solutions for medicine and coordinated participation by all stakeholders. We report here the use of a telehealth informatics-enabled and hospital-based telecare service for achieving productive PHM through providing a 24/7/365 user-centered telecare services to institutional and community users. These users are defined to include both care receivers and care providers. The hospital-based environment is important as it can greatly facilitate prompt access to both medical services and

individual's medical records.

II. Methods

The telehealth informatics platform enables the service operation and performance conducted by the Telehealth and Telecare Center (TTC) located in the Kaohsiung Medical University Hospital (KMUH) in Kaohsiung, Taiwan.

A. The Platform

The telehealth informatics platform used in this report is improved from the home-based telecare model used in an earlier study [10] and is similar to the system described previously [11]. The platform consists of five basic components including (1) a user-end vital sign monitoring and data transmission system, (2) an ID and security management system, (3) a service-end situation management system, (4) a central data storage system, and (5) a central data processing unit. The service-end situation management system is capable of performing a series of functions conducted by (i) a receiving unit for accessing individual's health data such as vital signs (EHR), electronic medical record (EMR) and life style related personalized health record (PHR), (ii) an evaluation unit for monitoring and analyzing individual's conditions based on his/her established vital sign baseline(s), integrated health records and personalized rating scale(s), (iii) a warning system for alerting the service team on occasions when any vital sign irregularities in relation to normal baseline are detected, and (iv) an interface unit for notification, recording, reporting and other communication actions.

B. The TTC

Brief background of the TTC was previously described [12]. The hospital-based 24/7/365 center had been accredited by the Ministry of Health (now MOHW) of Taiwan in 2009. The professional team at the center, which is supervised by a senior clinical staff at the KMUH, consists of registered nurses whose qualifications include substantial training in ER and/or ICU. To perform insightful health evaluations for and provide pertinent services to each individual, the team stringently follows the established process flows and procedures [11]. All rating scales, vital sign records and other relevant data are formatted and registered in the informatics platform system, and all conducts are performed in compliance with standard operating procedures (SOPs) established specifically for the operation of the center. In addition to the professional team, this center is also staffed by an informatics team, a maintenance team for calibrating and servicing devices, and an additional professional team for conducting site visits and other services. The site visits are critical for updating users' health conditions as well as collecting information on life style related health determinants.

C. Health Metrics and Evaluations

Health related data were collected from institutional and/or community users of the center service during the period of 2008-2016. Subsequent evaluation of the data was performed to examine any possible impacts of the services on preventive and/or interventional health outcomes. A total of 24,532 users were registered together with a sum of 1,084,816 service entries, 5,211 of which were enrolled in a regional community health program conducted between December 2014 and November 2016. To evaluate prevention related service outcomes, a systematic analysis on routine blood pressure (BP) monitoring against the blood pressure performance was conducted in accordance with length of using the center services. To determine surveillance related service outcome either in terms of correction of undetected health conditions, or avoidance of possible overuse or underuse of medical services, we conducted routine checking on users' vital sign irregularities and on medical histories of users receiving ongoing medical services. For the evaluation of service outcome in relation to any possible changes in disease progression, a group of service users, 365 individuals, with indication of at least one kind of chronic disease were selected for closer follow-ups with respect to further progression of the chronic disease(s). A survey of users' satisfaction was conducted in 2016 for service quality evaluation as well as for future improvement of services.

III. Results

A. Prevention Related Outcome

Blood pressure data obtained from a study group of 103 users who had used the center services consecutively for at least 10 months were evaluated. At each month point, the percentage of users (out of the whole study group) who performed routine BP measurement was compared against the percentage of users (out of the whole study group) who had irregular BP performance. The result of comparison indicates that longer service using has yielded more users taking routine BP measurement and fewer users showing BP irregularities. The percentage of users having routine BP measurement increases gradually from 35.6% to 84.1% during the ten months period, on the other hand, that of users with BP irregularity decreases gradually from 26% to 5%. We also observed that after the 6th month, there appears no significant change in increase in routine measurement or decrease in irregularity. It is encouraging to observe that a 2.4 fold increase in routine BP measurement has brought about a 5.2 fold reduction in incidence of BP irregularity. These results are similar to those reported previously in a study conducted at the KMUH [10].

B. Surveillance Related Outcome

Data collected from 2,654 service users enrolled between December 2014 and March 2016 were analyzed with respect to identifying any undetected health conditions among these users. This surveillance identified 276 users showing possible hypertension condition (HP), 88 users having possible diabetes condition (DB), and 66 users exhibiting possibly

both HP and DB, none of them had preexisting medical histories indicative of these conditions. After further observations, 28 service users were recommended to consult physician as soon as possible, 8 of them were confirmed with alarming HP condition and 3 with other threatening illnesses, and were subsequently treated. Potential benefits may be substantial in both health and financial terms.

In March 2017, one service user was detected to have been given overlapping medications after visiting two separate outpatient departments at a hospital in the same morning. This event was promptly identified by the TTC service team who was alerted by our telehealth informatics system that integrates the health records of service users. In this case, two prescribed drugs involved in the overlapping medication may have serious over dosing and adverse consequences. Our service team took immediate action to inform the user on such situation and avoided potential harms.

C. Emergency Care and Disease Progression Related Outcome

One major utility of telehealth monitoring of patient conditions is to assure prompt management of acute conditions like stroke. Between 2008 and 2016, we conducted a stroke condition related study involving a total of 226 center service users whom were referred by the center team to the emergency care at the KMUH as stroke onset suspects. Preliminary results from this study were reported previously [12]. Certain demographic characteristics of this group are as follows. There were 107 males with ages ranging between 52 and 98, and the median age was 73; the average age at the time of referral to the emergency department was 74.5. The figure for the females was 119 (52.7%) with ages ranging between 59 and 95, and a median age of 80, the average age at the time of referral was 79.3.

In 2008, 16 service users whom were identified as stroke suspects were referred to emergency care and the average time for them to arrive at hospital for emergency care was 32 minutes. For the subsequent years, the numbers of stroke suspects and arrival times, respectively, are: 2009, 18, 26 minutes; 2010, 35, 22 minutes; 2011, 43, 27 minutes; 2012, 26, 25 minutes; 2013, 28, 30 minutes; 2014, 12, 23 minutes; 2015, 22, 28 minutes; and 2016, 26, 23 minutes.

In a separate study, we investigated another potential utility of telehealth monitoring for chronic disease conditions such as HP and DB, and their progressions. Between 2008 and 2016, there were 365 service users whom were diagnosed to have one or more forms of chronic disease. Among them, 174 were males with ages ranging between 22 and 102. The average age was 72, and the median age, 72. More than half, 191 (52%), of these users were females with ages ranging between 41 and 95. Their average age was 76 and the median age, 77. Among those 211 service users who showed no stroke prehistory but had one or more forms of chronic conditions, and had been taking routine BP measurement after enrollment, only 2 of them (0.95%) suffered from the first-time stroke as compared to the reported significantly higher average rate of 8% in Taiwan [13, 14].

The 5-year secondary stroke rate for those 154 stroke patients who enrolled as the center service users between 2008 and 2016 was 3.25% (5 users) which is much lower than a reported rate of 30% in a study involving 675 patients [15]. Another study involving 9115 stroke survivors had reported a 5-year secondary stroke rate of 26.4% [16].

The stroke patient infection rate for the service users with stroke histories during the same period was 9.10% (14 out of 154 users) as compared to an overall infection rate of 30% reported in a larger scale study [17].

IV. Discussions

Our results demonstrate both functionality and usability of the hospital-based 24/7/365 TTC services which employ a working telehealth informatics platform and adopt a user-centered practice for conducting telecare and telehealth services. The results also show broad and significant outcomes relating to disease prevention, health surveillance, emergency care, and management of disease progression. As our user-centered telecare services are often provided to users in transiting care environment, our center is in a unique position for integrating all health networks, in particular, the family and community healthcare network. In fact, we have also used this service for supporting family and community practices, and in a broader context, demonstrated integration of relevant health networks. Therefore, by using the telehealth informatics-enabled telecare center, it is very likely that we be able to achieve an effective and productive coordinated care. Personalized long-term follow-up data acquired from such services also provide great opportunities for insightful clinical researches. These outcomes demonstrated by our center suggest that the center services may play significant roles in ensuring the health Triple Aim (better outcome, better user experience, and better cost-effectiveness), as well as better PHM through achievement of R6, i.e., 1) reducing time for patient to receive proper treatment, 2) reducing emergency visit rate, 3) reducing readmission rate, 4) reducing hospital stay, 5) reducing possible medical errors, and 6) reducing harms caused by possible overuse and/or underuse of medical services [9].

Since our service user satisfaction has been greater than 90%, it can be assumed that this type of telecare service is generally acceptable for a right cost. It is also noteworthy that the prevention related outcome seems to indicate that it may take, in general, six months for service users to adapt to a positive habit for preventive health.

P4 medicine (Personalized, Predictive, Preventive and Participatory), which features systems biology, digital advances, and large scale biomedical opportunities, has prompted pluralistic life technology innovations [7]. Among these innovations are a variety of newly developed devices, software, and wearable applications which require strong supports from the outcome-oriented and user-centered service practice in order to accomplish their strategic objectives. Furthermore, our service practice can serve as an effective testing field for validation of accuracy, functionality, interoperability, reliability, and usability for those applications. The recent survey reporting questionable accuracy in eight wearable devices intended for cardiovascular applications [18] has clearly indicated the

needs for practical standardization and effective validation of such technology applications. In view of ensuring productive use of ICT solutions, our service is needed for the development and improvement of these solutions for health and medicine.

Overall, as indicated by the outcomes achieved in relation to enhancing care and effective disease prevention, our outcome-oriented and user-centered service is a useful model for achieving better population health management as well as the health Triple Aim. Though, continuous improvement of service content and operation will be necessary in response to the rapidly advancing ICT and Omics.

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