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MOBILE SYSTEMS

The Smart Health Initiative in China: The Case of Wuhan, Hubei Province

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Abstract To introduce smart health in Wuhan, and provide some references for other cities. As the largest mega-city in central China, Wuhan is investing large amounts of resources to push forward the development of Smart Wuhan and Health Wuhan, and it has unique features. It is one of the centerpieces of China's New Healthcare Reform, and great hope is put on it to help solve the conflict between limited healthcare resources and the large population of patients. How to plan and design smart health is important. The construction of Wuhan Smart Health includes some aspects as follows, like requirement analysis, the establishment of objectives and blueprint, the architecture design of regional health information platform, evaluation and implementation, problems and solutions, and so on. Wuhan Smart Health has obtained some achievements in health network, information systems, resident's health records, information standard, and the first phase of municipal health information platform. The focus of this article is the whole construction process of smart health in Wuhan. Although there are some difficulties during this period, some smart health services and management have been reflected. Compared with other cities or countries, Wuhan Smart Health has its own advantages and disadvantages. This study aims to provide a reference for other cities. Because smart health of Wuhan is characteristic in construction mode. Though still in the initial stage, it has great potentials in the future.

Keywords Smart health · Regional health information platform · Information system · Smart city

Introduction

The information technology revolution that started in the last century has made current world different, and the healthcare industry has also entered a new era. Developed countries put forward the task of building sharing electronic health record (EHR) for every resident [1]. Accordingly, health information swept across all over the world [2]. Within the past few years, various new concepts have moved into the healthcare area, such as e-health (Electronic Health) [3], mobile devices [4], data science [5], m-health (Mobile Health) [6], smart health [7], etc.

Smart Health is one application of Smart City [8]. Smart City is defined by IBM as the use of information and communication technology to sense, analyze and integrate the key information of core systems in running cities. It can make intelligent response to different kinds of needs, including daily livelihood, environmental protection, public safety and city services, industrial and commercial activities [9]. Countries around the world, especially in Europe [10], America, Japan, and South Korea, are actively to carry out the related theory researches and technology explorations, excavate the city data resources, and develop the urban intelligent application system. China is also taking part in the Smart City [11], such as Beijing, Shanghai, Ningbo, Hangzhou, Guangzhou, Shenzhen, and Wuhan. Hong Kong aims to build the world's

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leading Internet of Things (IoT) applications [12]. Macao mainly focuses on the "people-based" information construction. The planning of Taiwan includes three stages [13]: (1) Taiwan's digital plan (2002–2007); (2) Taiwan's mobile plan (2005–2009); (3) smart Taiwan program (2009–2016). The core technologies include cloud computing, Internet of Things, mobile Internet, and big data technology.

In 2010, Wuhan Science and Technology Bureau held a news conference in order to release the global top-level design tender announcement of Wuhan Smart City. They planned to invest 10 million yuan on the overall planning and design of smart city. Finally, China Aerospace Science & Industry Corp won the tender. It spent 1 years and 8 months completing the plan (until July 2011). This is a smart city construction blueprint with the most perfect system, the most advanced ideas, and the most informative content in China. Healthcare is one of 15 key application fields. It is an origination in China because of the open and global project bidding. It is also a typical case in China owing to the concept design and overall planning.

Under the overall framework of Wuhan Smart City, the government paid high attention to Smart Health. On August 22, 2010, Ruan Chengfa, the Hubei Provincial Committee, and Wuhan party secretary, instructed related departments to vigorously promote intelligent medical information network in Wuhan. In 2011, the Wuhan government held the Seventh Session of the Twelfth National People's Congress, and proposed to promote the wisdom of medical convenience in the Wuhan Municipal People's Government Work Report. After doing some surveys, on August 12, 2011, Tang Liangzhi, mayor of Wuhan, pointed out that we should complete municipal health data center and three platform construction (medical services, public health, and health management) as soon as possible; integrate smart health into smart city information system construction; integrate smart health information system construction into the central medical service center plans. The community health service network covering the outskirts has been built for facilitating public medical treatment. In January 2012, China Aerospace Science & Industry Corp finished Planning and Design Schemes for Smart Health in Wuhan. In 2015, the government will build the municipal and district smart health service network. All these laid solid foundation for Wuhan Smart Health.

Wuhan is the largest city in central China, and among the top 10 megacities nationwide [14]. It has long been an economic, industrial and transportation hub for both the region and the country [15]. Its smart health construction has a very important reference value for others because of international oriented mode. As the core of the whole project, the municipal and district platform construction got significant attentions from Wuhan government. Its contents can be summarized as "two levels and three categories": build the municipal and district platforms using cloud computing and cloud storage technology; provide three kinds of smart health cloud services (healthcare, public health, and health management) based on electronic medical records database and resident's health records database. The two-level platform can realize information sharing in the Internet, and promote the orderly business development in the region.

This study takes Wuhan Smart Health as a case to describe the typical smart health construction mode in big city of central China. It may provide an effective solution for other urban constructions. Section "Background" introduces the present situation of the city and the status in healthcare area. Section "Materials and Methods" describes the design and implantation procedures of smart health in Wuhan. Section "Results" shows the current construction progress. Section "Discussion" expounds the contributions, measurements and comparisons with others. Section "Conclusion" is a brief conclusion.

Background

The basic condition of Wuhan

As the capital of Hubei Province, Wuhan is the largest mega-city in central China and in the middle reaches of Yangtze River [16]. Wuhan municipality is administratively stratified as district, sub-district (organized by street committee) and neighborhood (by residential committee). The urban administration of Wuhan consists of thirteen districts (Qiao Kou, Jiang Han, Jiang An, Han Yang, Wu Chang, Hong Shan, Qingshan, Lake of Dong Xi, Han Nan, Cai Dian, Jiang Xia, Xin Zhou, and Huang Pi). These spatial units are the major statistical sources of social and economic data. Wuhan has more than 8 million population now, and it is in the rapid development of population aging. The population of the elderly over 60 is 1.5601 million (accounting for 18.86 %). Life expectancy in Wuhan is 80.13 years, higher than the national average life expectancy (73.5 years old), and women's life expectancy is higher than men's.

Status quo in the health care industry

The total number of medical institutions in Wuhan City is 4485 (including 1703 village clinics), owning 72,827 health beds. The total number of health-care workers is 97,306 (including 78,492 health technical workers, 29,523 licensed doctors and assistant doctors, and 36,267 registered nurses). The number of outpatient visits in all health institutions is 68,070, 230, and there are 2,371,035 discharged patients. Specifically, there are 197 hospitals that can offer 60,127 beds. Their outpatient medical visits per year are 39,121,075, and inpatient medical visits per year are 2,029,500. For primary healthcare institutions, the total number is 4203 (including 1703 village clinics); the number of beds is 10,240; outpatient medical visits are 26,110,303 per year; inpatient medical visits are 251,321 per year. There are 73 public health authorities possessing 2460 beds. Their outpatient medical visits per year are 2,838,852, and inpatient medical visits are 95,349.

Now, health system in Wuhan can provide better healthcare for residents, which means that 8.85 health institutions beds per 1000 population, 7.31 hospital beds per 1000 population, 11.83 health-care workers per 1000 population, 9.54 health technical workers per 1000 population, and 3.59 physicians per 1000 population.

Materials and methods

In this section, we introduce how to plan and design a smart health in Wuhan, in order to help other cities to understand the whole process better, and even build their own smart health based on our study.

Requirement analysis

At the beginning stage, project contractor conducted a series of surveys in order to design the frame of Wuhan Smart Health. Investigations mainly involved the number of health institutions, the construction of basic network, status of health information system, and personnel training. Departments involved in the investigation are Health and Family Planning Commission of Wuhan Municipality, primary health care institutions of Health and Family Planning Commission in 14 district, pilot hospitals in Wuhan, and community health centers. Through these surveys, user's characteristics and their requirements were summed up.

(1) There have been computer rooms of information center in Health and Family Planning Commission of Wuhan Municipality; but, hardware expansion is indispensable for smart health information system.

(2) Electronic medical record (EMR) project in pilot hospitals and health information in community health centers have been going well; however, as for the media of recording patient's lifecycle data, resident health card has not been carried out.

(3) Most information systems (such as first-aid system, disease prevention system) have been finished; they are independent and decentralized yet, which cannot support information sharing.

(4) Hospitals in Wuhan are in a move from hospital management information system (HMIS) to hospital clinical information system (HCIS); but health information level between hospitals varies greatly.

(5) Most system architectures adopted C/S (Client/Server). Its deployment, upgrade, and maintenance are complicated. Only the Central Hospital of Wuhan considered the B/S (Browser/Server), and actively explored the construction of hospital information integration platform based on EMR.

Objective setting

According to the Opinions of the Communist Party of China Central Committee and the State Council on Deepening the Healthcare System Reform (the Opinions) Section 14, smart health project in Wuhan is aimed at developing the practical, and medical information sharing system [17].

Based on user's characteristics and their requirements in section 3.1, the specific objective is divided into two stages:

(1) The first stage will emphasize local health information infrastructure and the information construction of public health service. The use of EMR will be promoted as much as possible. Basic information systems, standard system, and security system will be gradually build. For medical data exchange and healthcare businesses collaborative management among all the medical agencies, the municipal and district information platforms will also be developed.

(2) The second stage will focus on public health information and primary health information. With Internet of Things and wireless mobile technology, residents in the communities or rural areas can enjoy more meticulous and efficient medical services with the intelligent terminals of family general practitioners. Finally, we would build an information connectivity and sharing architecture based on the municipal and district information platforms.

Blueprint

The route to Wuhan Smart Health was formulated after careful consideration of multiple factors in a macro and a micro level. The government compared the reality with "3521–2" project (China's health information system: three-level health information platform, five applications, two basic databases, one health network, one information standard system, and one information security system) which was drew up in the 12th five-year plan by National Health and Family Planning Commission of the People's Republic of China [18]. They also considered the "139″ plan (one basic information database, three platforms, and nine systems) which is one part of Cloud Computing Industry Development Action Plan in Wuhan. Its contents can be outlined as "1135″ blueprint:

(1) One network: dedicated network for smart health;
(2) One platform: smart health information platform, which is the core of the whole project. It contains the municipal and district information platforms, and three kinds of smart health cloud services (healthcare, public health, medical management). The former needs cloud computing and cloud storage technology; the latter is based on the EMR and EHR database.
(3) Three kinds of systems: basic support system, standard specification system and security system.
(4) Five types of applications: medical service, public health, medical insurance, medication supervision, and comprehensive management.

Design of architecture

In this section, we will describe how to design the architecture of the regional health information platform based on the residents' health records. It is the core part of smart health. Using advanced Internet technology [19], existing health information resources covering all health systems in Wuhan can be integrated in the platform. Relationship between smart health information platform and smart Wuhan is shown in Fig. 1. According to the specific objective and related technology standards, the whole framework of the platform is designed (seen in Fig. 2).

In order to satisfy certain technical requirements (the stability, advancement, openness, extensibility, and maintainability, etc.), the technical architecture of smart health platform uses SOA (Service-Oriented Architecture) architecture model [20], and data processing method combined the ETL (Extraction-Transformation-Loading) with the ESB (Enterprise Service Bus) [21]. It uses the XDS (Cross-enterprise Document Sharing) interagency document technology and medical BI data analysis techniques [22], and follows DICOM (Digital Imaging and Communications in Medicine), HL7 (Health Level Seven), XML (Extensible Markup Language), CDA (Clinical Document Architecture), and other technical standards or specifications [23]. The architecture mainly consists of four-tier as follows (seen in Fig. 3):

(1) The first tier is data source, which provides data source for district health information platform, keeps the data channel and the way to municipal health information platform constant.
(2) The second tier is data processing, which provides different and effective ways for processing standard and non-standard data from the data source layer, and put them into the repository or data warehouse according to the relevant standards and methods. For improving information resources construction in the district health data center, this layer is responsible for data extraction, including business data, public health reporting data, health records data. At the same time, other health business interaction data are also processed through the standard interface.
(3) The third tier is data center, which is designed for unified data management from the platforms. On the one hand, it needs to support data sharing and exchange of all kinds of business applications on the platform. On the other hand, it is responsible for data cleansing, transformation, loading, mining, and analysis to provide data support for comprehensive health management applications.
(4) The fourth tier is data application, which contains the business application systems on district health information platform. It can provide information system application services for various users (residents, medical institutions, health administrative departments, public health and family planning institutions, etc.).

In order to ensure the regional health data sharing and exchange, the implementation model provides the middle table definition, Web Services, and the EXCEL format data through the website filling (shown in Fig. 4).

Smart health network is the information base of smart health. For accessing all health institutions in Wuhan, the network topology of smart health information platform is designed as Fig. 5.

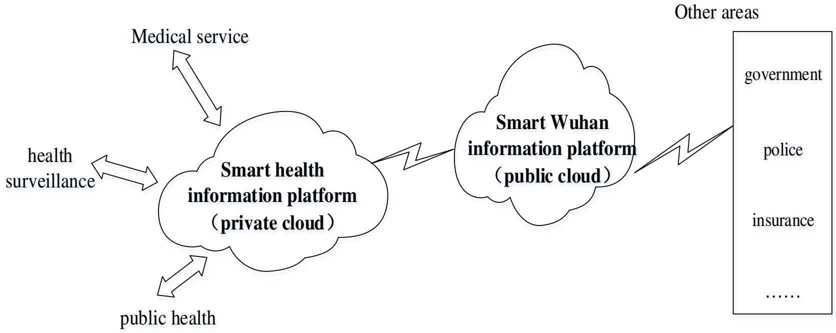

Medical service
Other areas
government
health surveillance
Smart health information platform (private cloud)
Smart Wuhan information platform (public cloud)
police
insurance
……
public health

Fig. 1 The relationship between the smart health information platform and Smart Wuhan

Evaluation

(1) In each phase of architecture and design, we considered that the focuses of health records management are the city and the district. Therefore, Wuhan municipal platform is responsible for residents' registration management, integration and storage of their health records, and pushing back these information to the district. Besides, electronic health records database and electronic medical records database are included. Because specific health business will be integrated in the municipal platform. In order to provide services for all medical institutions, the platform can support information sharing, business collaboration, integrated health management and public service.

(2) In order to guarantee information sharing across the city in the future, the platform construction referred to the provincial health information platform standards, like based on Health Records Platform Construction of the Regional Health Information Guide.

(3) Information security considered six aspects: physical security, network security, host security, application security, data security and security management. The whole system construction conforms to the state three-level information system protection requirements.

(4) Dedicated network for smart health can ensure that interconnection between medical institutions of all levels. Its construction referred to business support network architecture (backbone network and access network) by Health and Family Planning Commission of Hubei

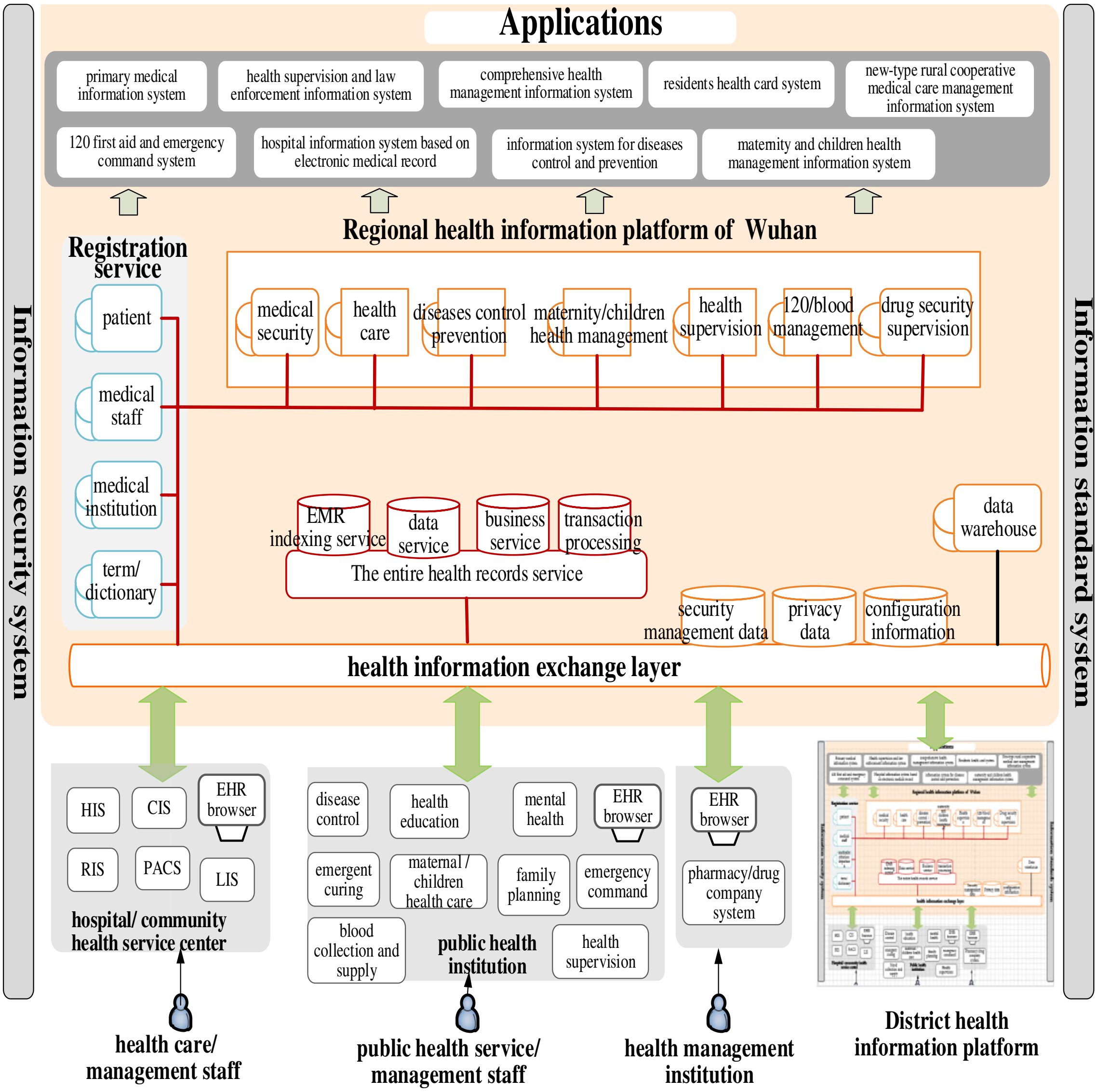

Applications
primary medical information system
health supervision and law enforcement information system
comprehensive health management information system
residents health card system
new-type rural cooperative medical care management information system
120 first aid and emergency command system
hospital information system based on electronic medical record
information system for diseases control and prevention
maternity and children health management information system
Information security system
Information standard system
Regional health information platform of Wuhan
Registration service
patient
medical staff
medical institution
term/ dictionary
medical security
health care
diseases control prevention
maternity/children health management
health supervision
120/blood management
drug security supervision
EMR indexing service
data service
business service
transaction processing
The entire health records service
data warehouse
security management data
privacy data
configuration information
health information exchange layer
HIS
CIS
EHR browser
RIS
PACS
LIS
hospital/ community health service center
disease control
health education
mental health
EHR browser
emergent curing
maternal / children health care
family planning
emergency command
blood collection and supply
public health institution
health supervision
EHR browser
pharmacy/drug company system
health care/ management staff
public health service/ management staff
health management institution
District health information platform

Fig. 2 The overall architecture of smart health information platform. Abbreviations: HIS, hospital information system; CIS, clinical information system; EHR, electronic medical record; RIS, radiology information system; PACS, picture archiving and communication system; LIS, laboratory information system

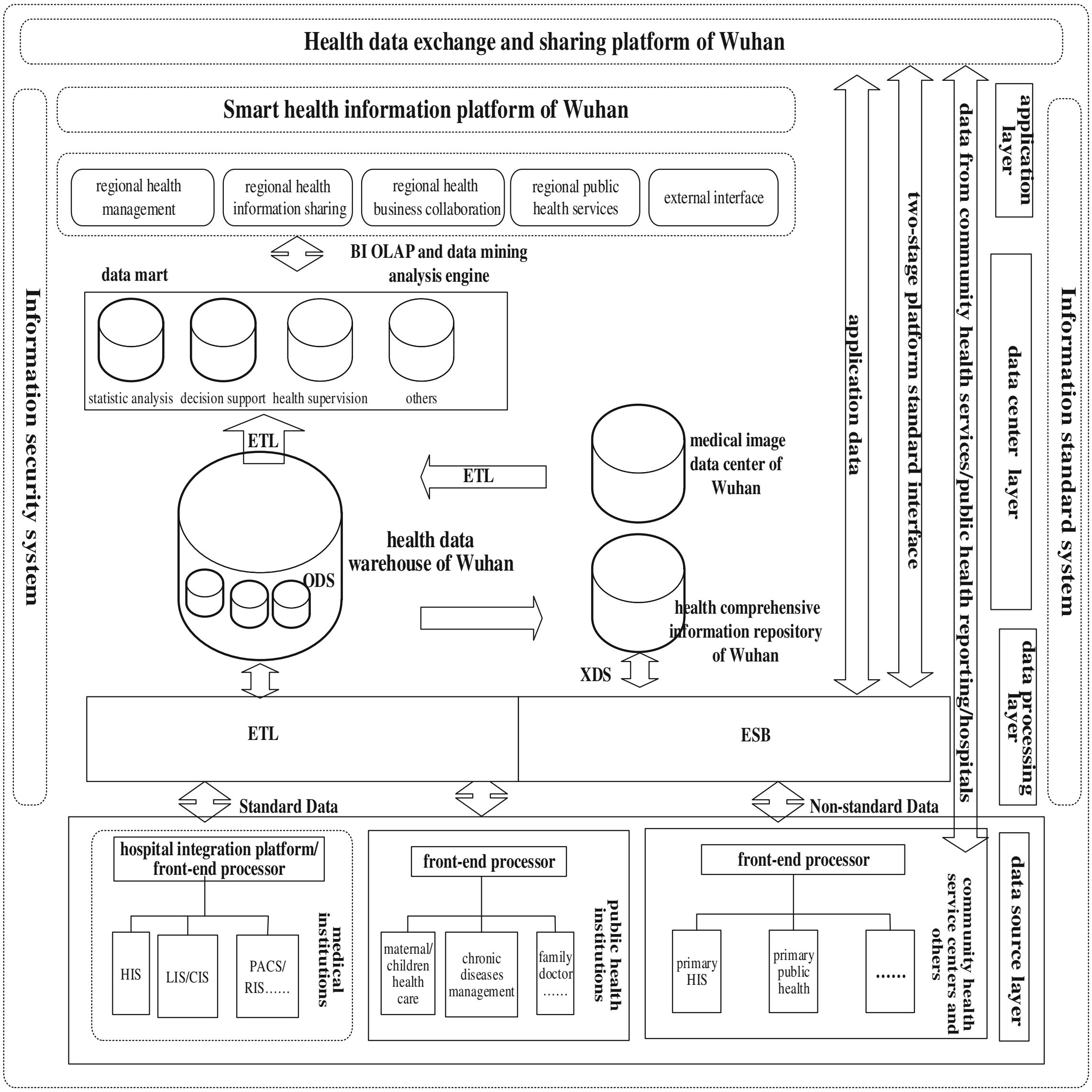

Health data exchange and sharing platform of Wuhan
Smart health information platform of Wuhan
regional health management
regional health information sharing
regional health business collaboration
regional public health services
external interface
BI OLAP and data mining analysis engine
data mart
statistic analysis
decision support
health supervision
others
ETL
ETL
health data warehouse of Wuhan
ODS
medical image data center of Wuhan
health comprehensive information repository of Wuhan
XDS
ETL
ESB
Standard Data
Non-standard Data
hospital integration platform/ front-end processor
HIS
LIS/CIS
PACS/ RIS……
medical institutions
front-end processor
maternal/ children health care
chronic diseases management
family doctor ……
public health institutions
front-end processor
primary HIS
primary public health
……
community health service centers and others
Information security system
application data
two-stage platform standard interface
data from community health services/public health reporting/hospitals
application layer
data center layer
data processing layer
data source layer
Information standard system

Fig. 3 The technical architecture of smart health information platform. Abbreviations: BI, business intelligence; OLAP, on-line analytical processing; ODS, operational data store; ETL, extraction-transformation-loading; XDS, cross-enterprise document sharing; ESB, enterprise service bus; HIS, hospital information system; LIS, laboratory information system; PACS, picture archiving and communication system; CIS, clinical information system; EHR, electronic medical record; RIS, radiology information system

Province. It can be isolated from other public networks [24].

Quality of Service (QoS) factors of dedicated internet

Considering data transmission requirements of whole application system, link quality requirements of health information network are as follows:

(1) In the case of 80 % network load, the ping command (1000 bytes) is executed, and the delay time is less than 30 ms;
(2) In the case of 80 % network load, the jitter value of data transmission should be less than 30 ms;
(3) Network packet loss rate is not more than 0.5 %;
(4) Device interconnection port should adopt fixed duplex mode, fixed-rate mode, and fixed MTU (Maximum Transmission Unit);
(5) Audio and video stream transmission are not suggested to pass through the network link constructed by the firewall, all kinds of encryption or encapsulation tunnel;
(6) The operator shall be responsible for the deployment, installation, configuration, maintenance and other work of the optical fiber or access equipment in the access terminal;

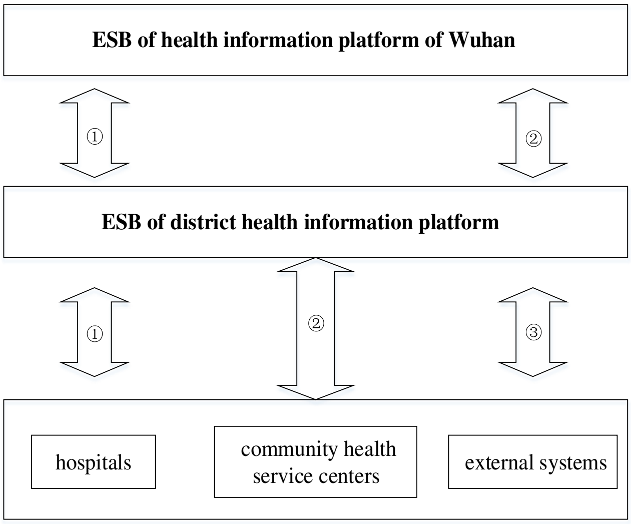

ESB of health information platform of Wuhan
①
②
ESB of district health information platform
①
②
③
hospitals
community health service centers
external systems

Fig. 4 The implementation model of data sharing and exchanging interface technique. Abbreviations: ESB, Enterprise Service Bus. NOTES: ①standard data interface adopted middle table integration mode; ②Interface followed the HL7 standard and Web Service communication protocol; ③web site data in Excel format. The municipal and district information platform both support the following data types: HL7 v2.x (health level seven), HL7 3.0, XML (extensible markup language), CDA (clinical document architecture), X12, DICOM (digital imaging and communications in medicine). Data protocols, such as HTTP (hypertext transfer protocol), JMS (java message service), LLP (line link pulsing), SOAP (simple object access protocol), TCP (transfer control protocol), are both accepted on the two information platforms

(7) High security is needed. The access network from the community health service centers (or community health service stations) to the city-level data center shall be isolated from the Internet or other network;
(8) All lines can be smoothly upgraded in the future business growth.

Implementation and application

First, build the dedicated network. The operator is responsible for the deployment, installation, configuration, maintenance and other work of the optical fiber or access equipment in the access terminal. According to the different network features and connection characteristics, the whole network system is classified into two layers: backbone network and access network. The backbone network is composed of a provincial nodes, 21 city prefecture nodes, and 91 counties or districts nodes. Network protocols include TCP/IP protocol (Transmission Control Protocol/Internet Protocol), Gigabit backbone technology, three-layer interaction technology, VLAN protocol (Virtual Local Area Network protocol), and so on [25]. Network security measures include link redundancy, equipment redundancy, firewall isolation, intrusion protection, etc. Municipal bureau of health accesses to the health network through the bare fiber or 50Mbps lines or higher. The bandwidth of county health bureau line is at least 20 Mbps. The bandwidth of public health agencies line requires at least 100Mbps. Second-class or above hospitals need 100Mbps lines or higher. Primary health institutions and private medical institutions are at least 4Mbps.

Second, promote hospital information. In March 2011, Wuhan municipal government formulated Electronic Medical Record Functional Specifications for Second Class above Hospital of Wuhan City. 16 hospitals (the union medical college hospital, Wuhan general hospital of Guangzhou military, and central hospital of Wuhan, etc.) were listed as pilot hospitals to vigorously promote the use of electronic medical records. In 2012, hospital information and the first phrase of information platform were conducted at the same time. Municipal bureau of health provided information systems for small hospitals with the support of government funds, and large hospitals independently developed information systems under the help of subsidies.

Third, lay down the information standard. In 2012, Wuhan municipal smart health information system standards project started. Participants included Health and Family Planning Commission of Wuhan Municipality, Wonders Information CO., LTD., and Huazhong University of Science and Technology. The research content includes five types of standard: the system function standard, the platform access guide, the resident health card supplementary standard, the classification and encoding standard, and data exchange standard.

In 2015, other works are going on, such as second stage of the municipal health information platform construction, the district health information platform, and information security system.

Problems and solutions

In the whole process, there were many barriers, and the government also positively took various measures.

First, lack of a clear top design for the development of smart health [26]. Many hospitals are building their information systems according to their own standards, which is not only a poor use of resources, but also introduces obstacles for future higher-level integration by reason of unified architectures. So the project group only collected the necessary data from the perspective of the overall consideration.

Second, lack of unified rules and industry standards for smart health platforms. Many technical problems existed at the beginning, like data collecting, storing, transferring, processing, and sharing. Therefore, the government and Information Technology (IT) companies together developed the unified interface standard and data quality management system.

Third, medical institutions have little understanding of smart health, and have few passion for it. There is no doubt that smart health will benefit the patients and society. However, for their own interests, large proportions of hospitals are not keen on building the smart health platform and providing the services. Because it will send part of their patients to lower-level hospital, which will shrink the profits of the former ones. Another reason is the high cost of the smart health basic platforms and service systems, training cost, and so on. Then the government issued documents, organized training courses for medical staff, paid bonuses to the supporter, and carried out performance management of hospitals, which were prepared for the access to the regional health platform and to ensure the project schedule.

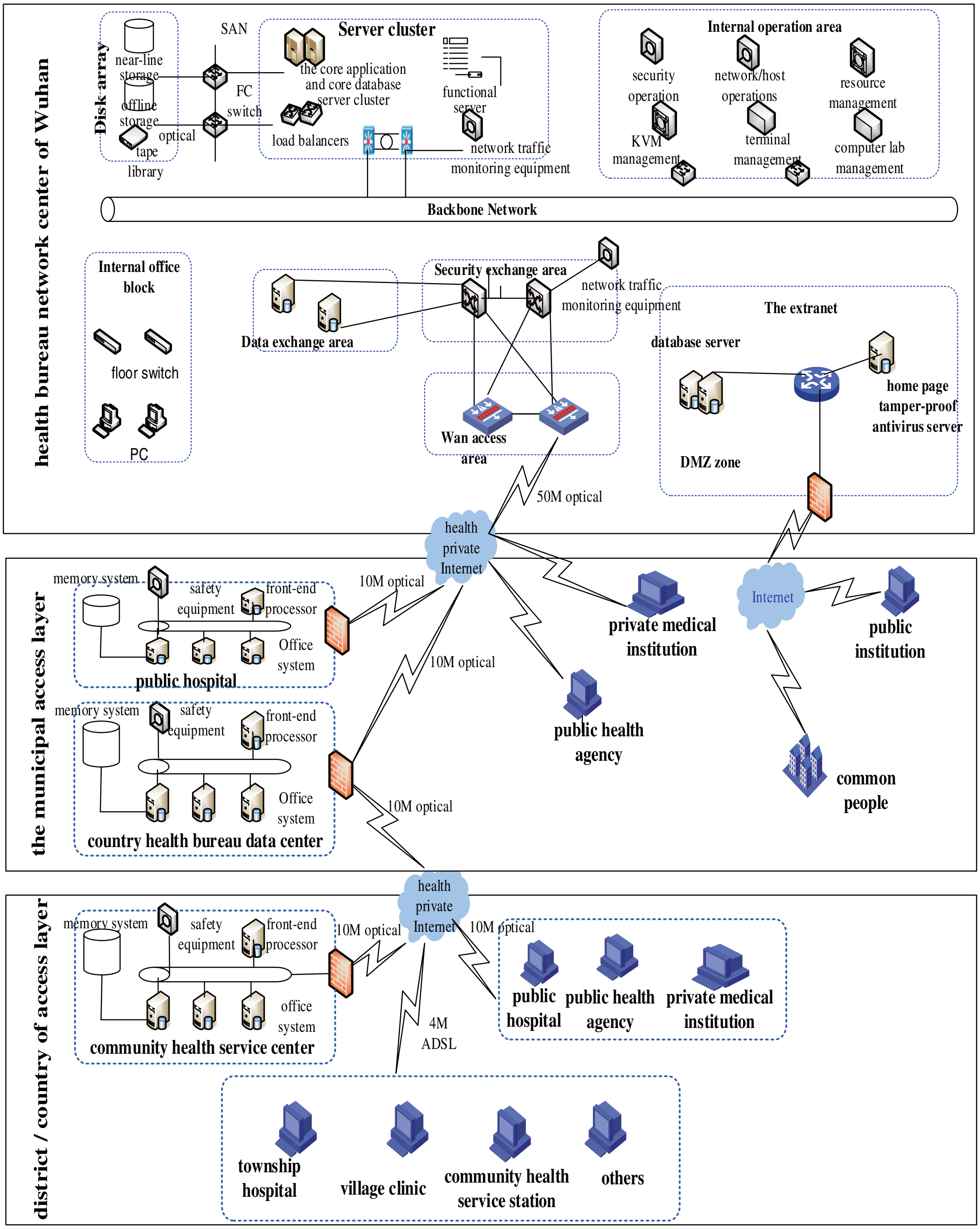

health bureau network center of Wuhan
Disk array
near-line storage
offline storage
tape library
optical
SAN
FC switch
Server cluster
the core application and core database server cluster
load balancers
functional server
network traffic monitoring equipment
Internal operation area
security operation
network/host operations
resource management
KVM management
terminal management
computer lab management
Backbone Network
Internal office block
floor switch
PC
Data exchange area
Security exchange area
network traffic monitoring equipment
Wan access area
The extranet
database server
home page tamper-proof antivirus server
DMZ zone
50M optical
health private Internet
the municipal access layer
memory system
safety equipment
front-end processor
Office system
public hospital
10M optical
country health bureau data center
private medical institution
public health agency
Internet
public institution
common people
district / country of access layer
4M ADSL
community health service center
office system
public hospital
township hospital
village clinic
community health service station
others

Fig. 5 The network topology of Wuhan Smart Health. Abbreviations: SAN, storage area network; FC, fiber channel; KVM, keyboard video mouse; PC, personal computer; DMZ, demilitarized zone; ADSL, asymmetric digital subscriber line

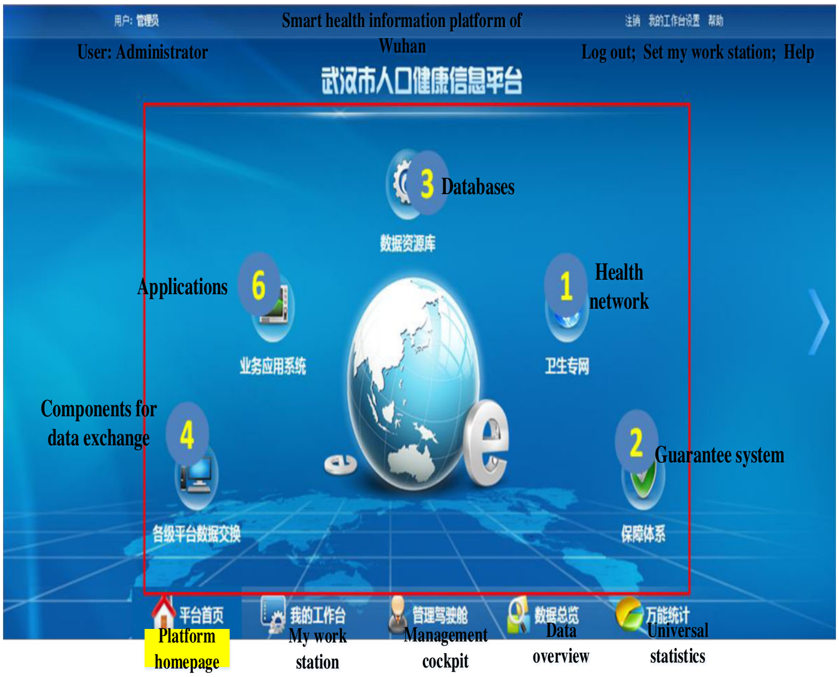

用户: 管理员
User: Administrator
Smart health information platform of Wuhan
注销 我的工作台设置 帮助
Log out; Set my work station; Help
武汉市人口健康信息平台
3 Databases
数据资源库
Applications 6
业务应用系统
1 Health network
卫生专网
Components for data exchange 4
各级平台数据交换
2 Guarantee system
保障体系
平台首页 Platform homepage
我的工作台 My work station
管理驾驶舱 Management cockpit
数据总览 Data overview
万能统计 Universal statistics

Fig. 6 Homepage of Wuhan Smart Health Information Platform

Results

While the government is making efforts in pushing forward the development of general healthcare systems and their standardization for smart health, many enterprises and organizations are trying to solve technical problems and make intelligent healthcare (IH) applicable in practice. They have made substantial achievements in the following aspects.

Information network

Information network is the basic guarantee for data transmission and business collaboration. Regional health network in Wuhan

Fig. 7 Interface 1 of my work station

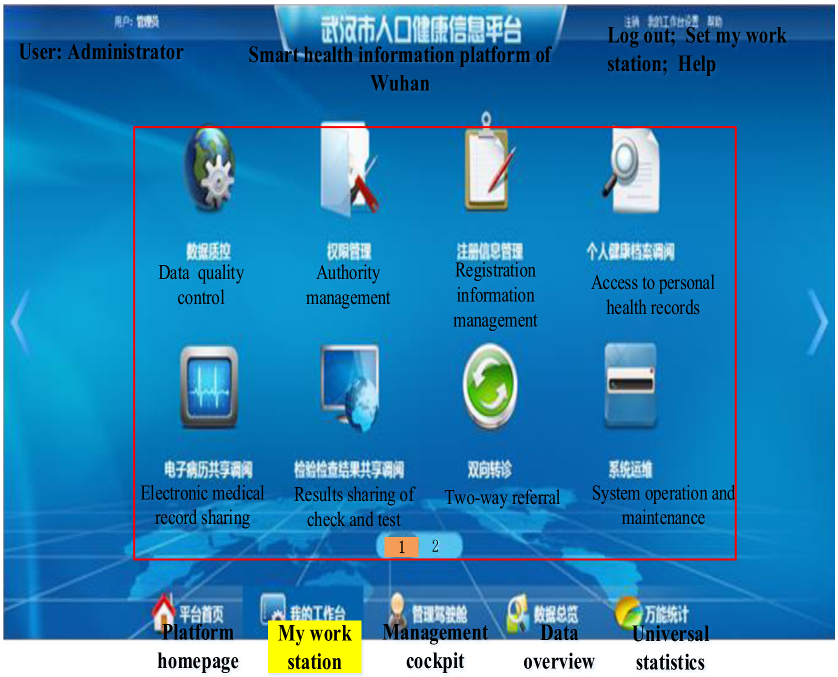
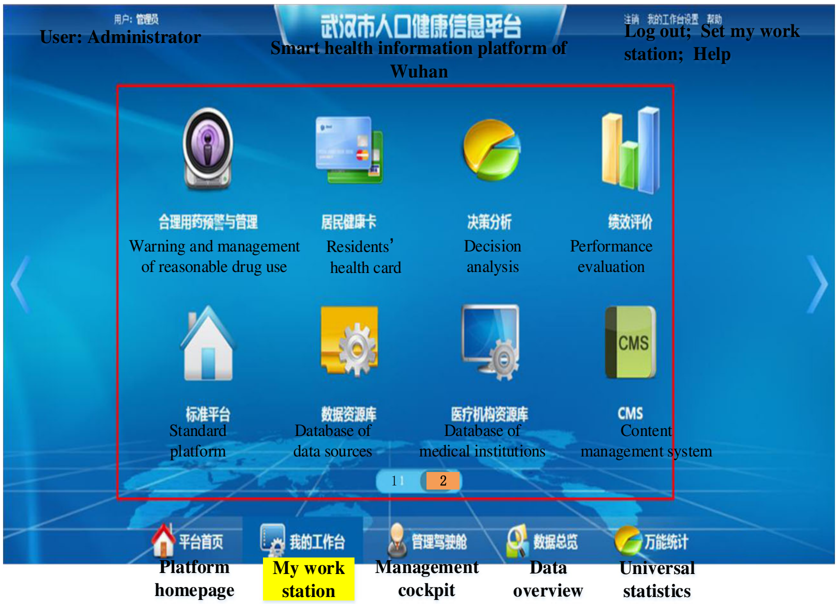

用户: 管理员
User: Administrator
武汉市人口健康信息平台
Smart health information platform of Wuhan
注销 我的工作台设置 帮助
Log out; Set my work station; Help
数据质控 Data quality control
权限管理 Authority management
注册信息管理 Registration information management
个人健康档案调阅 Access to personal health records
电子病历共享调阅 Electronic medical record sharing
检验检查结果共享调阅 Results sharing of check and test
双向转诊 Two-way referral
系统运维 System operation and maintenance
1 2
平台首页 Platform homepage
我的工作台 My work station
管理驾驶舱 Management cockpit
数据总览 Data overview
万能统计 Universal statistics

Fig. 8 Interface 2 of my work station


用户: 管理员
User: Administrator
武汉市人口健康信息平台
Smart health information platform of Wuhan
注销 我的工作台设置 帮助
Log out; Set my work station; Help
合理用药预警与管理
Warning and management of reasonable drug use
居民健康卡
Residents' health card
决策分析
Decision analysis
绩效评价
Performance evaluation
标准平台
Standard platform
数据资源库
Database of data sources
医疗机构资源库
Database of medical institutions
CMS
Content management system
1
2
平台首页
Platform homepage
我的工作台
My work station
管理驾驶舱
Management cockpit
数据总览
Data overview
万能统计
Universal statistics

has been constructed now, covering all the hospitals, community health service centers, rural service station and disease control and prevention system. It supports different means of querying. All the businesses from subordinate medical agencies can be transferred to the network, and be accessed into the outside network through the interface for external use.

Information standard

Information standard is one important guarantee system for smart health information platform. During the following years, many standards have been issued, which can be classified into five components:

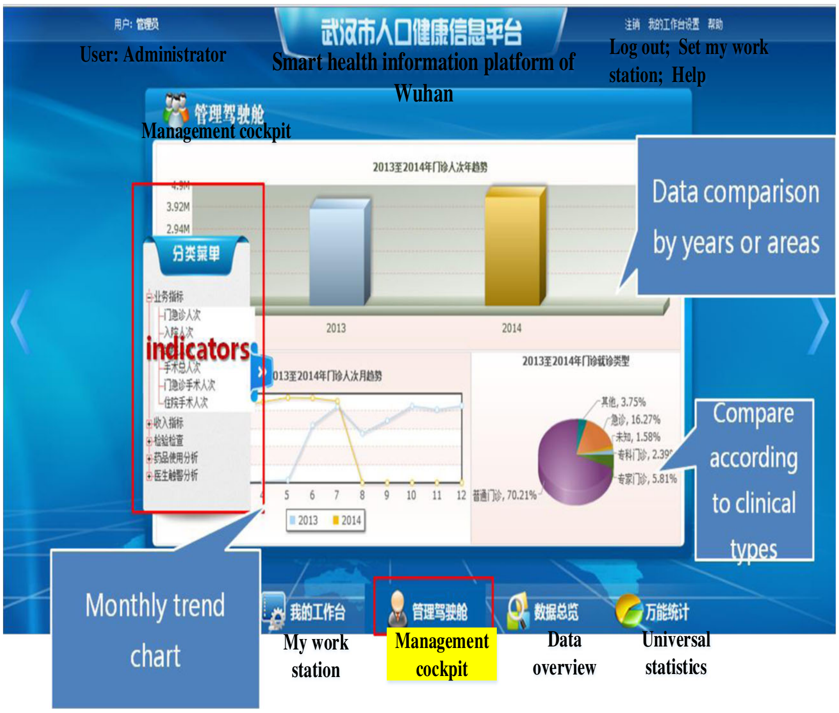

用户: 管理员
User: Administrator
武汉市人口健康信息平台
Smart health information platform of Wuhan
注销 我的工作台设置 帮助
Log out; Set my work station; Help
管理驾驶舱
Management cockpit
2013至2014年门诊人次年趋势
3.92M
2.94M
2013
2014
Data comparison by years or areas
分类菜单
业务指标
门急诊人次
入院人次
indicators
手术总人次
门急诊手术人次
住院手术人次
收入指标
检验检查
药品使用分析
医生触警分析
2013至2014年门诊人次月趋势
5
6
7
8
9
10
11
12
2013
2014
2013至2014年门诊就诊类型
其他, 3.75%
急诊, 16.27%
未知, 1.58%
专科门诊, 2.39%
专家门诊, 5.81%
普通门诊, 70.21%
Compare according to clinical types
Monthly trend chart
我的工作台
My work station
管理驾驶舱
Management cockpit
数据总览
Data overview
万能统计
Universal statistics

Fig. 9 Management cockpit interface. Indicators include business indicators, income indicators, check and examination indicators, drug use analysis, doctor error warning analysis. Business indicators include outpatient and emergency visits, admission number, discharge number, total operation number, outpatient and emergency operation number operation number of admission. In this case, we can know the differences and changes between 2013 year and 2014 year from three dimensions

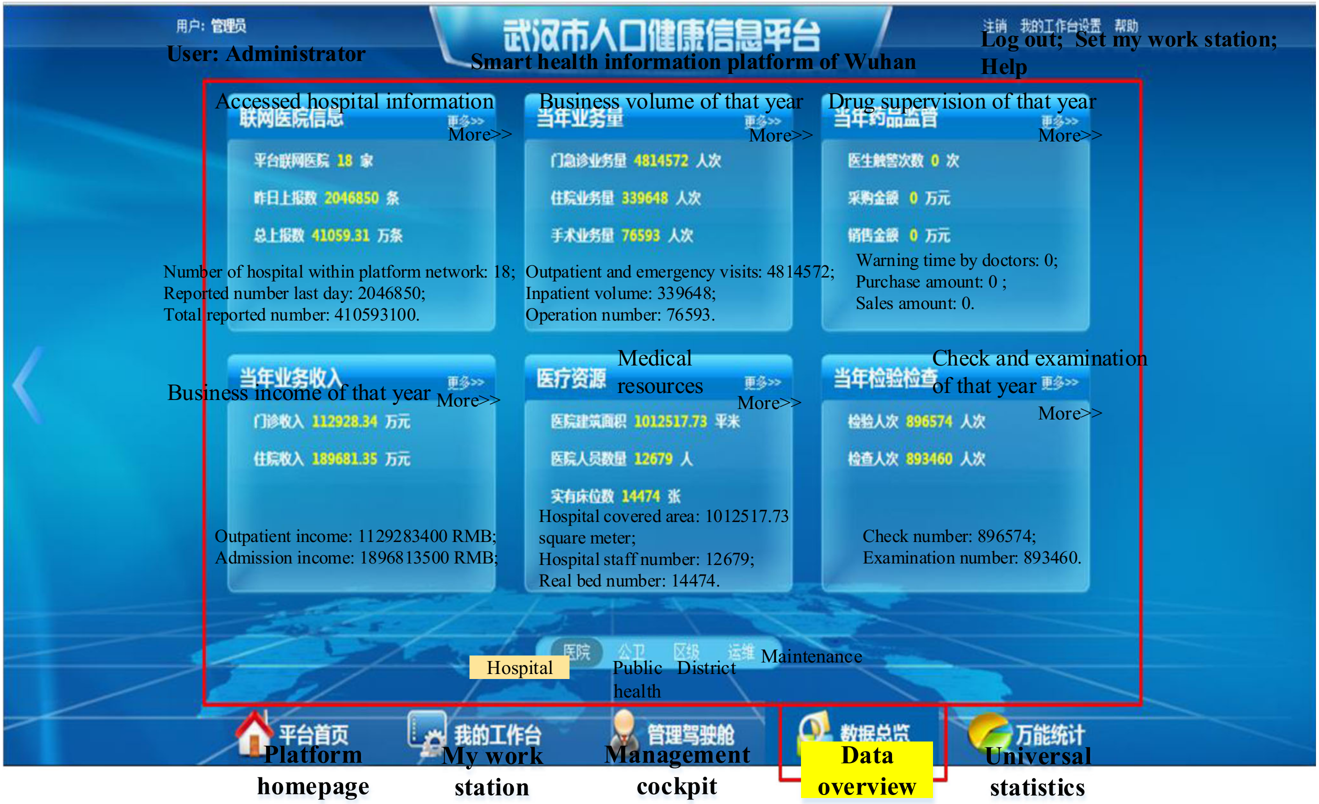
a. The first one is standards for information platform, like Construction Specification for District-level Regional Health Information Platform of Wuhan, Functional Specification for Hospital Information Platform of Wuhan based on EMR.
b. The second one is standard guides, such as Standards Guide for Smart Health Information System of Health and Family Planning Commission of Wuhan Municipality, Standards and Specifications for Smart Health Information System of Health and Family Planning Commission of Wuhan Municipality.
c. The third one is management standards. For example, Health Information Sharing Specification for EMR and Laboratory and Examination, Standards for Public Health Services Portal Real-name Authentication of Wuhan Municipality, and Specifications for Two-way Referral Business Implementation.
d. The fourth one is interface standards, like Standards for Health Service Data Interface on Regional Health Information Platform of Wuhan, Classification and Coding for Value Domain of Health Data Element on Regional Health Information Platform of Wuhan.
e. The last one is standards for resident's health card, which are Administrative Policy for Wuhan Residents Health Card, Construction Scheme for Wuhan Residents Health Card Pilot Project, and Information System Matching Renovation Specification for Health Institutions Application of Wuhan Residents Health Card. The security system will begin in 2015.

Information platform

18 hospitals accessed to the regional health information platform of Wuhan, and the number of hospitals has increased to 28 in May 2015. The second phrase project bidding of the municipal health information platform has been completed. Construction of district health information platform has also begun in 2015.

The main achievements in the first phrase is health information platform (seen in Fig. 6). It includes five parts (at the bottom in Fig. 6): platform homepage, my work station, management cockpit, data overview, and universal statistics.

(1) Section "platform homepage" presents five supporting contents: four components for data


用户：管理员
User: Administrator
武汉市人口健康信息平台
Smart health information platform of Wuhan
注销 我的工作台设置 帮助
Log out; Set my work station; Help
联网医院信息
Accessed hospital information
更多>>
More>>
当年业务量
Business volume of that year
更多>>
More>>
当年药品监管
Drug supervision of that year
更多>>
More>>
当年业务收入
Business income of that year
更多>>
More>>
医疗资源
Medical resources
更多>>
More>>
当年检验检查
Check and examination of that year
更多>>
More>>
医院
Hospital
公卫
Public health
区级
District
运维
Maintenance
平台首页
Platform homepage
我的工作台
My work station
管理驾驶舱
Management cockpit
数据总览
Data overview
万能统计
Universal statistics

平台联网医院 18 家
昨日上报数 2046850 条
总上报数 41059.31 万条

Number of hospital within platform network: 18;
Reported number last day: 2046850;
Total reported number: 410593100.

门急诊业务量 4814572 人次
住院业务量 339648 人次
手术业务量 76593 人次

Outpatient and emergency visits: 4814572;
Inpatient volume: 339648;
Operation number: 76593.

医生触警次数 0 次
采购金额 0 万元
销售金额 0 万元

Warning time by doctors: 0;
Purchase amount: 0 ;
Sales amount: 0.

门诊收入 112928.34 万元
住院收入 189681.35 万元

Outpatient income: 1129283400 RMB;
Admission income: 1896813500 RMB;

医院建筑面积 1012517.73 平米
医院人员数量 12679 人
实有床位数 14474 张

Hospital covered area: 1012517.73 square meter;
Hospital staff number: 12679;
Real bed number: 14474.

检验人次 896574 人次
检查人次 893460 人次

Check number: 896574;
Examination number: 893460.

Fig. 10 Four dimensions of data display. It includes hospitals, public health, the district state, maintenance (the second line from the bottom). In this case, we clicked the hospital, then some data enter our sight (from top to down, from left to right: hospital information within network, business volume, drug supervision, business income, medical resources, check and examination of that year.)

exchange, six applications, three databases, one health network, and two guarantee systems. Two guarantee systems mean information standard system and information security system. The former has been finished; the latter began in 2015, and goes well now.

(2) Section “my work station” mainly includes 16 applications based on the platform (shown in Fig. 7 and Fig. 8).

(3) Data query, data comparison, and trend analysis can be achieved in Section “management cockpit”. As shown in Fig. 9.

(4) Section “data overview” can show data according to four dimensions (hospital, public health, district-level, and maintenance), as illustrated in Fig. 10. Click on the yellow number, you can see the details of the indicator (shown in Fig. 11).

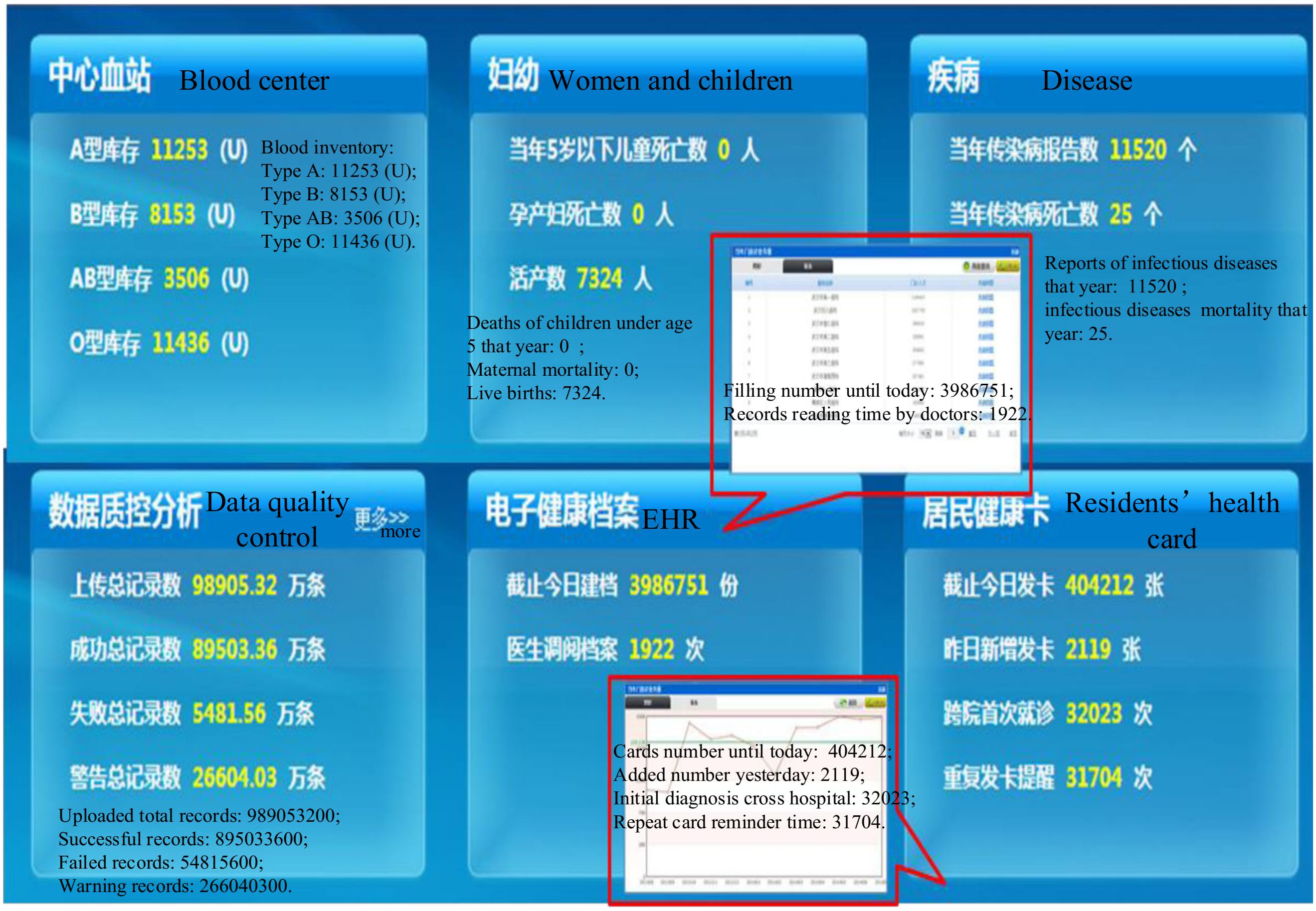
(5) Section “universal statistics” provides optional query according to user habits like Taobao.com. Then select and query indicators. We can see the process in Fig. 12.

Data quality control

Data is the base of all the applications. Its quality directly influences the effects of applications. Consequently, complete data quality guarantee system is built, covering data acquisition, data check, and data use. Data will be evaluated by a complete set of interface data quality assessment system on data exchange platform. This assessment mainly highlights the quality state of data uploaded from the healthcare agencies within the network. It includes two parts: the upload quality and the upload stability. In addition, data can be controlled by two kinds of mechanism. The first is to monitor the communication node of the healthcare agencies within the network in real-time by front end processors. The results can be shown in the form of a list or graph. The second is to monitor the business data operation. Data quality control interface is shown in Fig. 13.

Case study

With the payment reform on new rural cooperative medical system financing and the population health information



中心血站 Blood center

A型库存 11253 (U)
B型库存 8153 (U)
AB型库存 3506 (U)
O型库存 11436 (U)

Blood inventory:
Type A: 11253 (U);
Type B: 8153 (U);
Type AB: 3506 (U);
Type O: 11436 (U).

妇幼 Women and children

当年5岁以下儿童死亡数 0 人
孕产妇死亡数 0 人
活产数 7324 人

Deaths of children under age 5 that year: 0 ;
Maternal mortality: 0;
Live births: 7324.

疾病 Disease

当年传染病报告数 11520 个
当年传染病死亡数 25 个

Reports of infectious diseases that year: 11520 ;
infectious diseases mortality that year: 25.

Filling number until today: 3986751;
Records reading time by doctors: 1922.

数据质控分析 Data quality control 更多>> more

上传总记录数 98905.32 万条
成功总记录数 89503.36 万条
失败总记录数 5481.56 万条
警告总记录数 26604.03 万条

Uploaded total records: 989053200;
Successful records: 895033600;
Failed records: 54815600;
Warning records: 266040300.

电子健康档案 EHR

截止今日建档 3986751 份
医生调阅档案 1922 次

Cards number until today: 404212;
Added number yesterday: 2119;
Initial diagnosis cross hospital: 32023;
Repeat card reminder time: 31704.

居民健康卡 Residents’ health card

截止今日发卡 404212 张
昨日新增发卡 2119 张
跨院首次就诊 32023 次
重复发卡提醒 31704 次

Fig. 11 Query of indicator details. Abbreviations: EHR, electronic health record. In this case, when we clicked EHR, two line records showed up. First is the latest filling number 3,986,751. Second is the accessed filling number by doctors 1922. Residents’ health card is the same as EHR

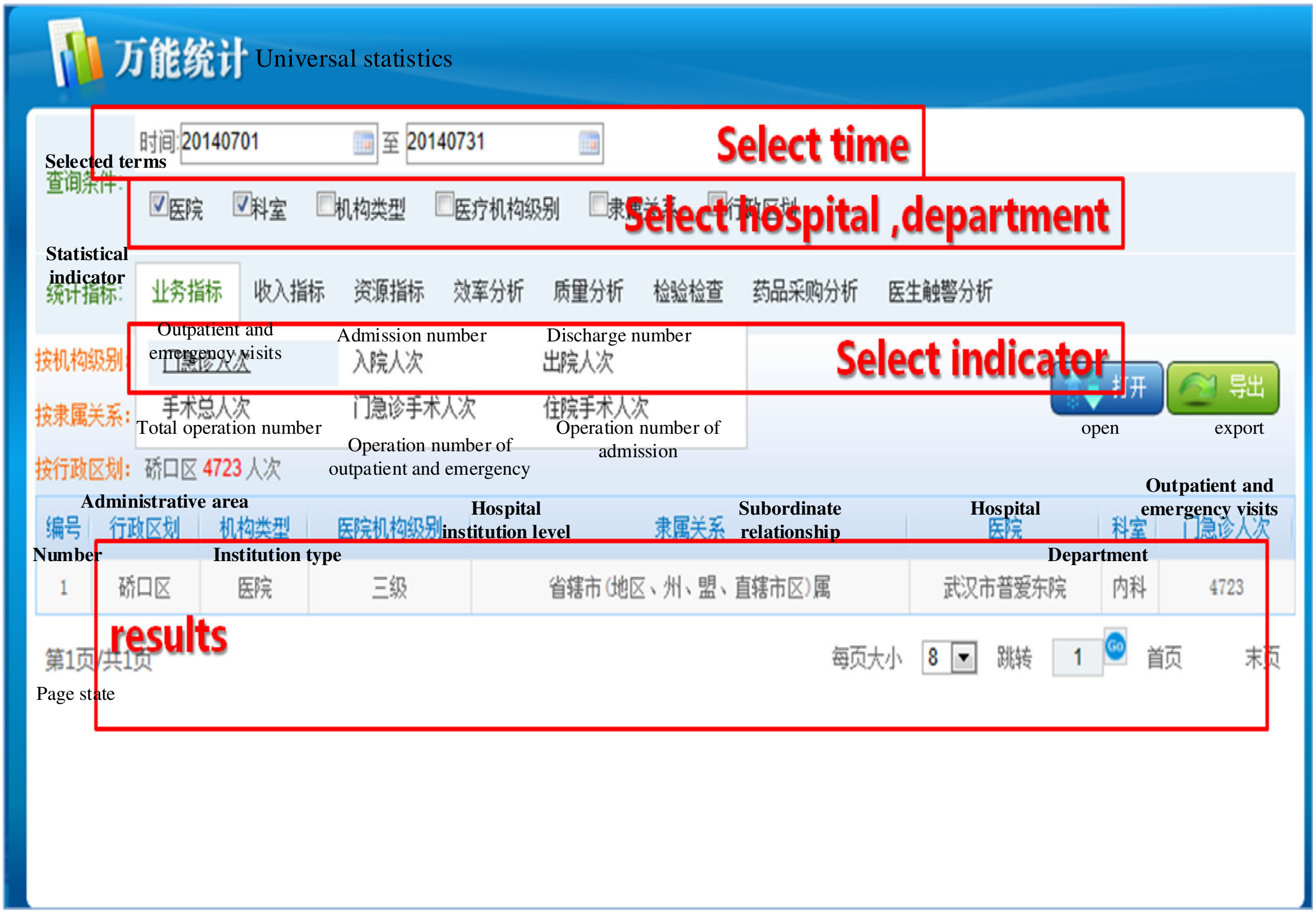
construction, project development of residents' health card has been completed in 2014. In January 2014, residents' health card (magnetic stripe card) is put into use in 18 hospitals; In June 2014, Jiang Xia District and the central hospital of Wuhan began to prepare for granting national health card (CPU (Central Processing Unit) card). Jiang Xia District of Wuhan was the first batch of concentrated distribution pilot area. The cards were issued to residents over 16 years old. These people have taken part in the new rural cooperative medical system. In 2015, coverage of residents' health card in Wuhan will reach 50 %, and full coverage in 2016.

Taking the residents' health card usage as an example, you can easily understand the operation of health information platform in Wuhan. Two media of health cards are suitable for Wuhan residents' health card system, as shown in Fig. 14. As an important application on the platform, it facilitates the medical treatment flow (Fig. 15). Additionally, by reading the personal health records, the doctor can know more detailed information (like recent medication, recent visit, and laboratory test report) to make a better decision for patients.

Discussion

Most studies focused on the theoretical research, such as system architecture [27], key technologies [28], smart wearable health applications [29], smart health monitoring systems [30], smart city and smart health [31], influential factors of smart health users [32], acceptance of smart health care services [33], and so on. This study summed up some experiences of Wuhan Smart Health in order to provide reference for other cities.

The whole process of smart health in Wuhan includes the following links: requirement analysis, goal setting, blueprint plan, architecture design, and implementation. During this period, challenges are mushrooming everywhere. The main point is the practical route to smart health. The second is the smart level. The reasons for these problems are mainly lack of holistic planning and integrated technical solutions, excessive dependence on government departments, and inadequacy cooperative mechanism. Therefore, the government developed a series of ways to solve these problems. For instance, create a route to smart health and the


万能统计 Universal statistics
Select time
Selected terms
查询条件:
Select hospital ,department
Statistical indicator
统计指标:
业务指标
收入指标
资源指标
效率分析
质量分析
检验检查
药品采购分析
医生触警分析
Select indicator
按机构级别:
按隶属关系:
Outpatient and emergency visits
门急诊人次
Admission number
入院人次
Discharge number
出院人次
手术总人次
Total operation number
门急诊手术人次
Operation number of outpatient and emergency
住院手术人次
Operation number of admission
打开
open
导出
export
results
Page state
每页大小
跳转
Go
首页
末页

时间: 20140701 至 20140731

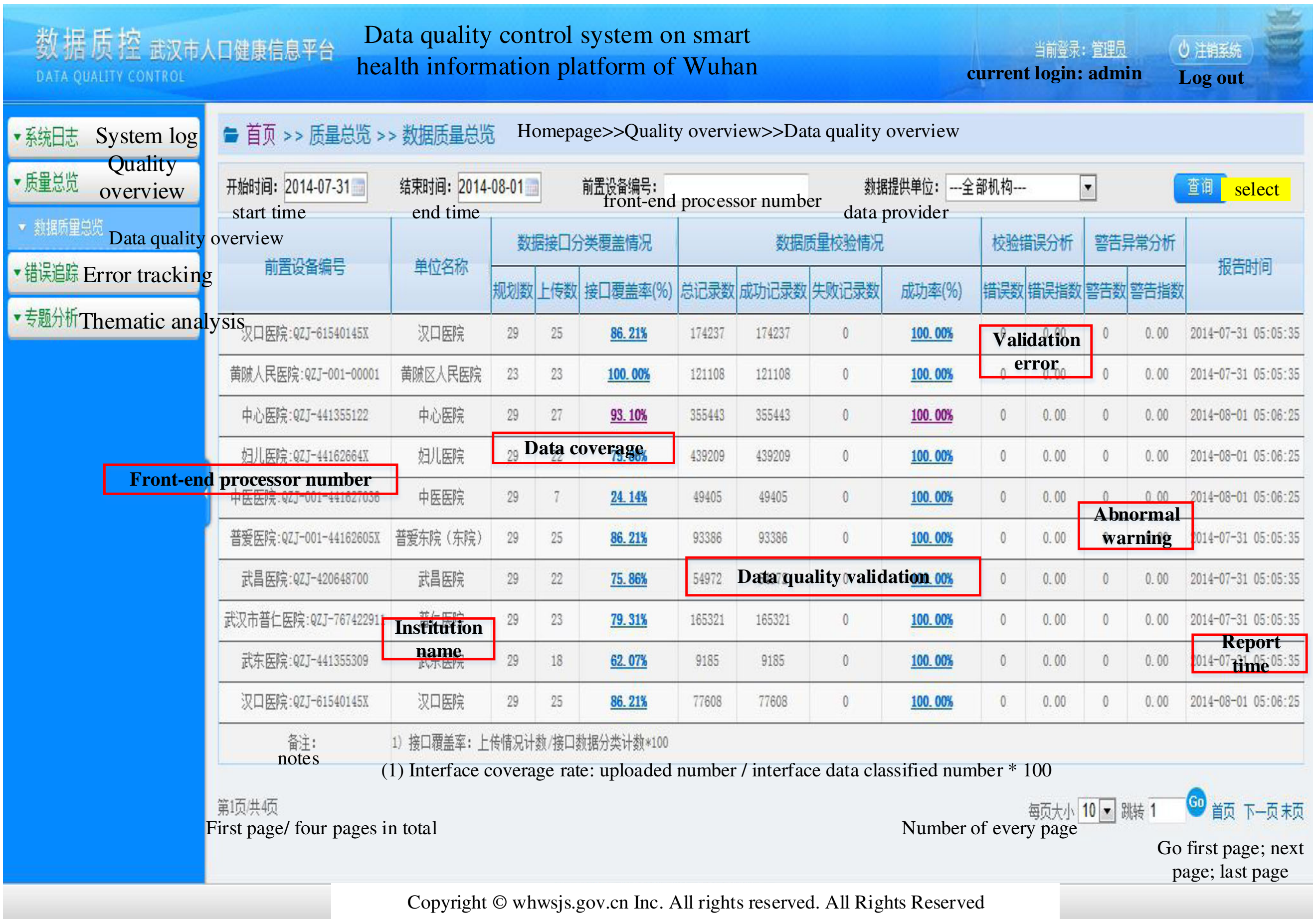
☑医院 ☑科室 □机构类型 □医疗机构级别 □隶属关系 □行政区划

按行政区划: 硚口区 4723 人次

编号 Number	行政区划 Administrative area	机构类型 Institution type	医院机构级别 Hospital institution level	隶属关系 Subordinate relationship	医院 Hospital	科室 Department	门急诊人次 Outpatient and emergency visits
1	硚口区	医院	三级	省辖市(地区、州、盟、直辖市区)属	武汉市普爱东院	内科	4723

第1页/共1页 每页大小 8 跳转 1

Fig. 12 Statistical result query. Statistical Indicators include business indicators, income indicators, resource indicators, efficiency indicators, quality indicators, check and examination indicators, drug purchase analysis, doctor error warning analysis. In this case, we selected outpatient and emergency visits of hospitals and departments in Qiaokou District from July 1, 2014 to July 31, 2014. The result is Pu'ai hospital in Wuhan



数据质控 武汉市人口健康信息平台 DATA QUALITY CONTROL

Data quality control system on smart health information platform of Wuhan

当前登录：管理员 current login: admin

注销系统 Log out

系统日志 System log
质量总览 Quality overview
数据质量总览 Data quality overview
错误追踪 Error tracking
专题分析 Thematic analysis

首页 >> 质量总览 >> 数据质量总览 Homepage>>Quality overview>>Data quality overview

开始时间：2014-07-31 start time

结束时间：2014-08-01 end time

前置设备编号： front-end processor number

数据提供单位：---全部机构--- data provider

前置设备编号	单位名称	数据接口分类覆盖情况			数据质量校验情况				校验错误分析		警告异常分析		报告时间
		规划数	上传数	接口覆盖率(%)	总记录数	成功记录数	失败记录数	成功率(%)	错误数	错误指数	警告数	警告指数	
汉口医院:QZJ-61540145X	汉口医院	29	25	86.21%	174237	174237	0	100.00%	0	0.00	0	0.00	2014-07-31 05:05:35
黄陂人民医院:QZJ-001-00001	黄陂区人民医院	23	23	100.00%	121108	121108	0	100.00%	0	0.00	0	0.00	2014-07-31 05:05:35
中心医院:QZJ-441355122	中心医院	29	27	93.10%	355443	355443	0	100.00%	0	0.00	0	0.00	2014-08-01 05:06:25
妇儿医院:QZJ-44162664X	妇儿医院	29	22	75.86%	439209	439209	0	100.00%	0	0.00	0	0.00	2014-08-01 05:06:25
中医医院:QZJ-001-441627036	中医医院	29	7	24.14%	49405	49405	0	100.00%	0	0.00	0	0.00	2014-08-01 05:06:25
普爱医院:QZJ-001-44162605X	普爱东院（东院）	29	25	86.21%	93386	93386	0	100.00%	0	0.00	0	0.00	2014-07-31 05:05:35
武昌医院:QZJ-420648700	武昌医院	29	22	75.86%	54972	[illegible]	0	100.00%	0	0.00	0	0.00	2014-07-31 05:05:35
武汉市普仁医院:QZJ-76742291	普仁医院	29	23	79.31%	165321	165321	0	100.00%	0	0.00	0	0.00	2014-07-31 05:05:35
武东医院:QZJ-441355309	武东医院	29	18	62.07%	9185	9185	0	100.00%	0	0.00	0	0.00	2014-07-31 05:05:35
汉口医院:QZJ-61540145X	汉口医院	29	25	86.21%	77608	77608	0	100.00%	0	0.00	0	0.00	2014-08-01 05:06:25

备注： notes

1) 接口覆盖率：上传情况计数/接口数据分类计数*100

(1) Interface coverage rate: uploaded number / interface data classified number * 100

第1页共4页 First page/ four pages in total

每页大小 10 跳转 1 Number of every page

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Fig. 13 Data quality control interface. It is one section of information platform. You can select uploaded data quality during some time. Aspects include data coverage, data quality validation, and so on (seen in the red textbox). The state of data coverage includes: planning number, uploaded number, and interface coverage rate. Data quality validation includes total records number, successful records number, and failed records number. Analysis of validation includes error number and error index. Analysis of abnormal warning includes warning number and warning index

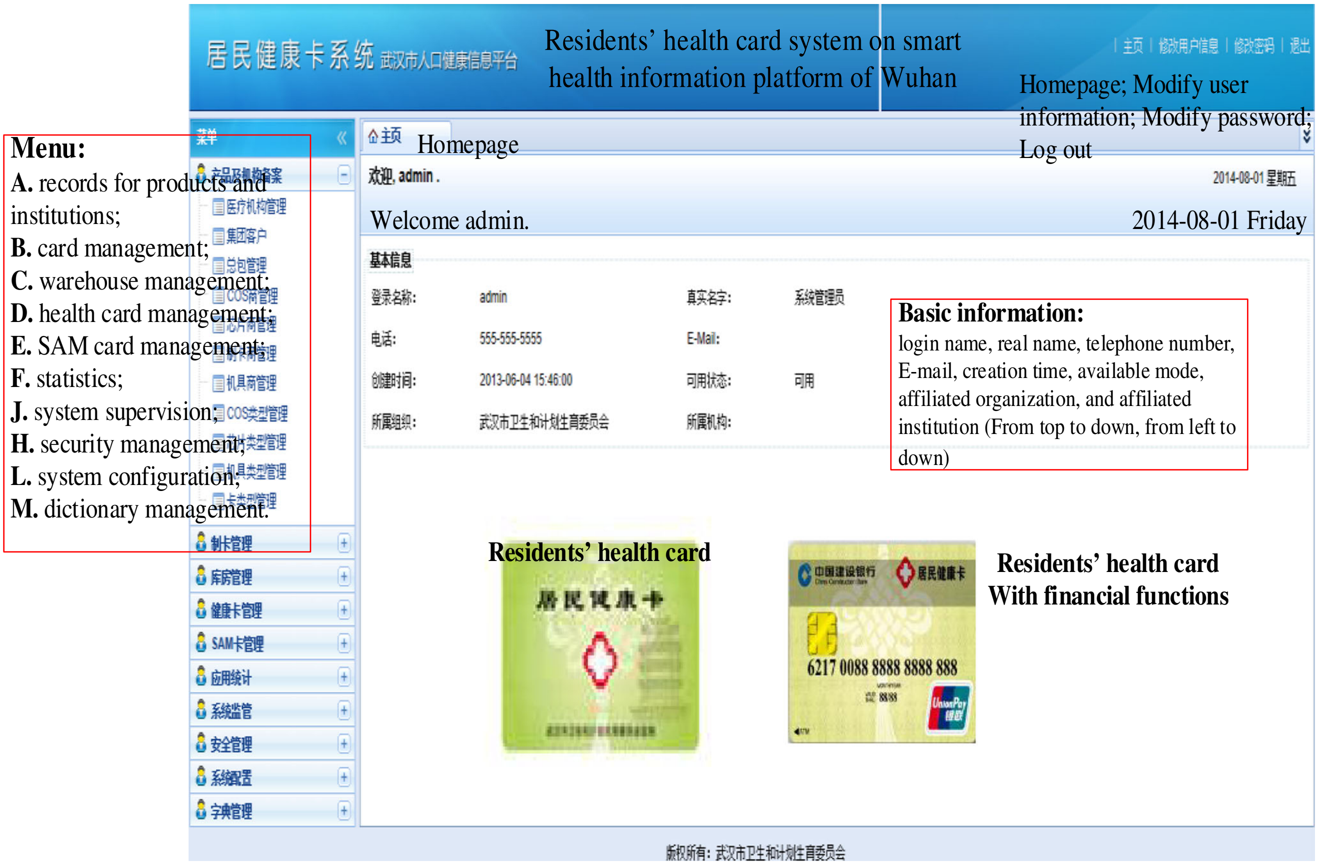
application of innovation technology, pay more attention to business systems, integration, standards, and create synergies between sectors.

Some intelligence can be seen in the service and management now. In 2010, the Central Hospital of Wuhan became the only pilot in the project for Wuhan smart health. Now when the patient needs to pay for the bill, queue is not necessary. A variety of payment methods are optional, such as credit card, and bank accounts. With the Bluetooth remote control technology, patients can also make an appointment, self-service query, and visit through video on the television screen. The doctor ward round and nurse care also use the smart health. At the diabetes center of this hospital, it is possible for doctors to remotely know patient vital signs information, write medical records, and make a decision with special tablets. According to the patients' electronic watches on the hand, the nurse can ensure that the patient identity matches with the doctor's advice information automatically. If there were differences, alarm warning messages will be sent from the system.

However, the project just finished a little part of work, and many things need to do in the future. Smart health public access platform has been built, but not yet open to the public because of personal privacy protection. Many electronic medical records cannot be matched to the electronic health records without ID number of patients. Therefore, for improving data quality, we need to encourage visits with real name.

Compared with other regions in China, the biggest difference of Wuhan Smart Health is top planning, synergy between sectors, and patient-centered care. In the early stages of the project, the government paid high attention to it, invested a lot of money in global bidding of integrated planning scheme. In implementation period, synergy between various sectors played a significant role, including the governments, hospitals, health administrative authorities, enterprises, and the public.

Smart health also develops very fast in other countries. For instance, many cities, regions, companies, knowledge institutions around Europe have already started smartering processes in cities and communities. Some experts created relevant methodologies to guide the development of smart city or smart health, including Smart City Dynamics, Open & User Driven Innovation methodologies, Semantic-based QoS Management


居民健康卡系统 武汉市人口健康信息平台
Residents' health card system on smart health information platform of Wuhan
| 主页 | 修改用户信息 | 修改密码 | 退出
Homepage; Modify user information; Modify password; Log out
菜单
产品及机构备案
医疗机构管理
集团客户
总包管理
COS商管理
芯片商管理
制卡商管理
机具商管理
COS类型管理
芯片类型管理
机具类型管理
卡类型管理
制卡管理
库房管理
健康卡管理
SAM卡管理
应用统计
系统监管
安全管理
系统配置
字典管理
主页
Homepage
居民健康卡
Residents' health card
中国建设银行
居民健康卡
6217 0088 8888 8888 888
Residents' health card With financial functions
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Menu:
A. records for products and institutions;
B. card management;
C. warehouse management;
D. health card management;
E. SAM card management;
F. statistics;
J. system supervision;
H. security management;
L. system configuration;
M. dictionary management.

欢迎, admin . 2014-08-01 星期五

Welcome admin. 2014-08-01 Friday

基本信息

登录名称: admin 真实名字: 系统管理员
电话: 555-555-5555 E-Mail:
创建时间: 2013-06-04 15:46:00 可用状态: 可用
所属组织: 武汉市卫生和计划生育委员会 所属机构:

Basic information:
login name, real name, telephone number, E-mail, creation time, available mode, affiliated organization, and affiliated institution (From top to down, from left to down)

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Fig. 14 Homepage of Wuhan residents' health card system. Abbreviations: COS, Class of Service; SAM card, Secure access module card. It shows some basic information of health card, including login name, real name, telephone number, E-mail, creation time, available mode, affiliated organization, and affiliated institution (from top to down, from left to down). In the lower right corner, you can see two kinds of health card. In the left Menu, records for products and institutions include: hospital management, group's customer, contract management, COS provider management, chip supplier management, card business management, equipment supplier management, COS type management, ship type management, equipment type management, and card equipment type management

Framework [34]. A number of projects, like CityPulse, Open Cities, is also underway. These methodologies and projects both emphasize people's needs; similarly, a part of Wuhan Smart Health vision is indeed people driven. However,

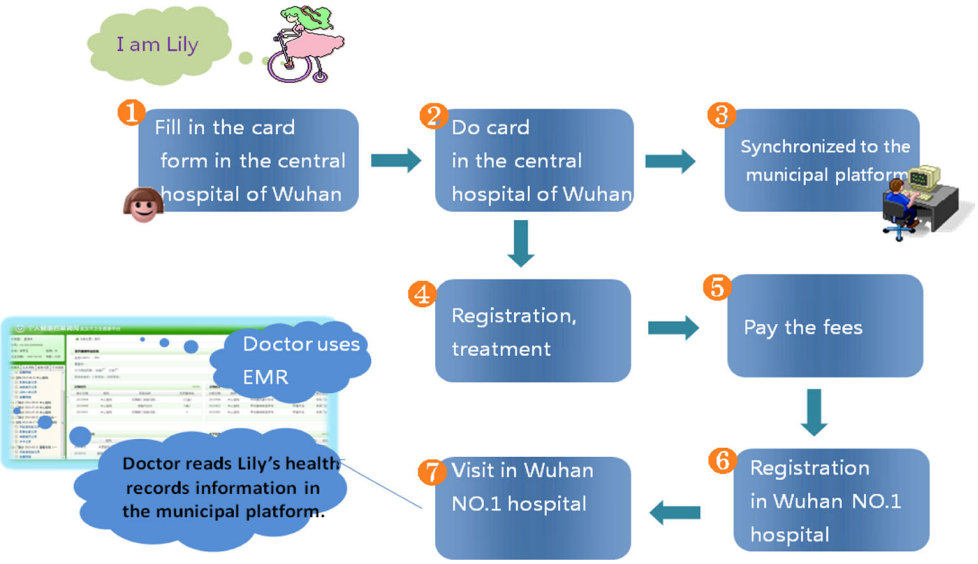
I am Lily
① Fill in the card form in the central hospital of Wuhan
② Do card in the central hospital of Wuhan
③ Synchronized to the municipal platform
④ Registration, treatment
⑤ Pay the fees
⑥ Registration in Wuhan NO.1 hospital
⑦ Visit in Wuhan NO.1 hospital
Doctor uses EMR
Doctor reads Lily's health records information in the municipal platform.

Fig. 15 Medical treatment process of residents with health card in Wuhan

Wuhan Smart Health is slightly inferior in Open Innovation methodologies (Open Data, Living Labs methodologies, etc.) than other countries. These fields should also be significant research directions.

Conclusions

Planning and construction of smart health in Wuhan generally embodies the core smart services, like information platform. This study focused on the evaluation of the core project and health information platform architecture design in order to provide the useful information for other projects.

The development of smart health in Wuhan is still in its infancy with great potentials in the future. Wuhan has expended enormous efforts to promote the industry' growth, and has made some relevant achievements. All these are worth learning for other cities. The government of Wuhan is trying to improve the whole healthcare system. A series of standards and specifications have been published according to the national standards. Some basic information sharing networks have been established.

On the other side, hundreds of local companies have been growing very quickly, and some of them can provide advanced technologies, from smart hospitals to a regional healthcare system. Mobile healthcare based on wearable devices, big data, and cloud computing are exploding in China. Wuhan Optical Valley is becoming the base of these technologies. For example, the future optical valley cloud village will build complete ecological environment for big data and cloud computing.

However, many serious problems remain owing to the insufficient technical development and unbalanced distribution of healthcare resources. It will become an even more significant topic in the future because many new opportunities and challenges are appearing. Some aspects should be paid more attention to in the coming years for Wuhan:

(1) Complete the top design for smart health. A clear and implementable development framework from the government is the urgent need for the smart health industry in Wuhan. It is the guidance for all the remaining tasks.
(2) Improve the market environment to attract private capital into the healthcare area. Private investments have great potential to promote the smart health, but it stays away from the market now. Investors are hesitating mainly because they are not clear with the future of smart health, and there are no clear policies and laws to guide and regulate its development. The government should publish more favorable policies, like absorbing private healthcare institutions into the national insurance system, and simplifying the approval procedures.
(3) Support software companies to solve key technical problems. They are very significant for the development of smart health. They are the architects of final information platforms, and they know well what the customers need and where the weak points lie. However, most companies lack the courage and enough resources to do basic research. Therefore, the government should support some selected companies to do basic research and to lead the development of Wuhan Smart Health.

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