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EHR adoption across China's tertiary hospitals: A cross-sectional observational study

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ABSTRACT

Heading: EHR adoption across China's tertiary hospitals: a cross-sectional observation study
Objectives: To assess electronic health record (EHR) adoption in Chinese tertiary hospitals using a nation-wide standard EHR grading model.
Methods: The Model of EHR Grading (MEG) was used to assess the level of EHR adoption across 848 tertiary hospitals. MEG defines 37 EHR functions (e.g., order entry) which are grouped by 9 roles (e.g., inpatient physicians) and grades each function and the overall EHR adoption into eight levels (0–7). We assessed the MEG level of the involved hospitals and calculated the average score of the 37 EHR functions. A multivariate analysis was performed to explore the influencing factors (including hospital characteristics and information technology (IT) investment) of total score and scores of 9 roles.
Results: Of the 848 hospitals, 260 (30.7%) were Level Zero, 102 (12.0%) were Level One, 269 (31.7%) were Level Two, 188 (22.2%) were Level Three, 23 (2.7%) were Level Four, 5 (0.6%) was Level Five, 1 (0.1%) were Level Six, and none achieved Level Seven. The scores of hospitals in eastern and western China were higher than those of hospitals in central areas. Bed size, outpatient admission, total income in 2011, percent of IT investment per income in 2011, IT investment in last 3 years, number of IT staff, and duration of EHR use were significant factors for total score.
Conclusions: We examined levels of EHR adoption in 848 Chinese hospitals and found that most of them have only basic systems, around level 2 and 0. Very few have a higher score and level for clinical information using and sharing.

1. Introduction

Health information technology (HIT) has the potential to improve the efficiency and quality of modern healthcare systems [1,2]. While electronic health record (EHR) adoption and its use have been reported in both ambulatory and hospital settings of industrialized nations [3–11] including some Asian countries [12–16], few if any assessments exist on the level of EHR adoption in China or developing countries [17–20]. China is currently entering a New Medical Reform. One of the

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focuses of this new Medical Reform is the implementation of HIT, specifically EHRs, given their potential impact on healthcare quality and safety while controlling the cost. As a first step, we sought to evaluate the level of EHR adoption in China. Secondarily, we sought to identify what hospital factors may facilitate or impede EHR adoption. We utilized a nationwide standard EHR grading model called "MEG" or the Model of EHR Grading, developed by the Chinese Ministry of Health, for this purpose.

2. Background

Many countries have established national guidelines to assess EHR adoption and functionality. In the United States, the Office of the National Coordinator for Health Information Technology (ONC) supported national EHR adoption surveys led by the National Center for Health Statistics (NCHS) and the American Hospital Association (AHA) [21–24]. Similarly, the Healthcare Information and Management Systems Society (HIMSS) Analytics developed an EMR Adoption Model (EMRAM) to track EHR adoption in more than 5000 U.S. hospitals as well as sites in Canada, Europe and Asia [25]. In 2006, the Commonwealth Fund supported a survey to assess primary care physicians' adoption of EHR systems across 7 countries [3,6].

In developing countries, Sood et al. conducted a study that examined factors affecting EHR implementation and the populations covered by these EHR implementations. These factors included healthcare infrastructures, healthcare workforce, availability of training facilities, and barriers to language [19]. Articles addressing global e-Health were published in the Bulletin of the World Health Organization (WHO). For example, Tomasi et al. conducted a literature review on HIT on primary care in developing countries with a focus on electronic patient registries, evaluation and management systems, and clinical decision support (CDS) systems. However, only one Chinese study on diagnosis support systems was included in this review [26]. A recent study examined various types of information communication technology (e.g., phone, computer, camera, GPS, etc.) employed by private organizations to improve health financing and delivery in low- and middle-income countries. However, until now there are no published studies that exist on the level of EHR adoption in China [17].

2.1. EHR adoption and use in China

From 2009, the healthcare system in China has been going through a New Medical Reform to address rising difficulties in accessibility and affordability of its healthcare services for its citizens [27,28]. HIT serves as a key topic in the New Medical Reform given its potential impact on healthcare efficiency and effectiveness [29]. The New Medical Reform has stimulated several nation-wide initiatives to encourage and assess EHR adoption and implementation across all Chinese hospitals [18,30,31]. The Model of EHR Grading (MEG) was developed to fulfill this task. The MEG model described below is similar to EMRAM, which has been applied to several developed countries. This paper describes the first national-wide evaluation of current EHR adoption in China. Tertiary hospitals were selected as the subjects in this initial evaluation due to the following reasons. First, due to similar costs of care between primary, secondary and tertiary hospitals, patients in China tend to prefer tertiary hospitals even for common conditions, resulting in a larger population being served by these hospitals. Second, tertiary hospitals often take on teaching and research activities and are pioneers in adopting HIT. Third, this evaluation requests hospital self-reporting their data online to the MEG system, which requires multiple sessions of training. Tertiary hospitals often have necessary IT staff and are capable of fulfilling the evaluation tasks.

3. Methods

3.1. Defining EHR

The EHR Functional Specification published by the Ministry of Health (MOH) of China in 2010 has been adopted to define an EHR in Chinese hospital settings. Similar to definitions used by other countries, EHRs are defined as computer information systems supporting data collection, storage and access in hospitals or healthcare centers, for the purpose of providing information and knowledge across diverse settings to improve healthcare quality, safety and efficiency.

3.2. Model of EHR Grading (MEG)

MEG was built based upon previous work on EHR adoption measures (e.g., HIMSS' EMRAM) and EHR functionality evaluation [32]. We combined and expanded these methods to accommodate the differences in the hospital structure, clinical workflow and regulations unique to Chinese hospitals.

For the purpose of evaluating EHR adoption of Chinese hospitals, MEG was drafted in early 2010 by a group of Health IT leaders and experts in China. Through an iterative process, the model was further revised and validated through a series of module-focused working sessions specializing in EHR functionality across different hospital departments, including radiology, laboratory, pharmacy, nursing, and management. Stakeholders from government, hospitals, universities, and vendors provided feedback to further improve the draft. Near the end of 2011, MEG was launched by the MOH of China. The National Institute of Hospital Administration (NIHA) cultivated a data center for the online collection of MEG and other related data.

3.3. MEG measurements

MEG currently defines a total of 37 EHR functions that are used for assessing the overall adoption level of an EHR. These functions are grouped by 9 different roles. Table 1 demonstrates the 9 roles, associated EHR functions with each role, and the mechanism for calculating the usage of each function.

MEG assesses EHR adoption first by assessing its level of functionality. It grades the adoption of each function into eight levels (0–7). Inpatient Physician Order Entry is used as an example to demonstrate the eight levels of an EHR function, as described in Table 2. At each grade level, each function is defined as either a "core" or "optional" function required for achieving the corresponding overall EHR adoption level. For

Table 1 – EHR roles, functions and usage defined in MEG.

Roles	Functions	Usage
Inpatient physicians	Order entry	% of overall discharged patients
	Laboratory test requests	% of inpatient laboratory tests
	Viewing laboratory reports	% of inpatient laboratory tests
	Examination requests	% of inpatient examinations
	Viewing examination reports	% of inpatient examinations
	Inpatient reports (including admission notes, progress notes and discharge summaries)	% of overall discharged patients
	Clinical decision support and knowledge bases	% of clinical departments
Inpatient nurses	Patient assessment and management	% of hospital units
	Order entry	% of hospital units
	Nurse documents	% of overall discharged patients
Outpatient physicians	Order entry	% of overall outpatient orders
	Laboratory requests	% of overall outpatient laboratory tests
	Viewing laboratory reports	% of overall outpatient laboratory tests
	Examination requests	% of overall outpatient examinations
	Viewing examination reports	% of overall outpatient examinations
	Clinic visit notes	% of overall outpatient visits
	Clinical decision support and knowledge bases	% of outpatient departments
Ancillary departments and services (e.g., Radiology)	Requests and appointments	% of overall examinations
	Patient records	% of overall examinations
	Report generation	% of overall examinations
	Images	% of overall examination images
Laboratory	Sample processing	% of overall laboratory tests
	Result records	% of overall laboratory tests
	Report generation	% of overall laboratory tests
Procedures (e.g., surgeries and treatments) and ICU	Procedure and treatment records	% of overall procedures and treatments
	Surgery scheduling, registration and records	% of overall surgeries
	Anesthesia	% of overall surgeries
	ICU monitory data	% of overall monitory equipments
Blood center, pharmacy and other ancillary departments	Blood preparation	% of overall blood transfusions
	Blood matching and use	% of overall blood transfusions
	Outpatient pharmacy	% of overall outpatient orders
	Inpatient pharmacy	% of overall discharged patients
Records management	Quality control	% of overall discharged patients
EHR infrastructure	Data storage	% of record time
	E-authentication and e-signature	% of overall number of systems
	Data access control and auditing	% of overall number of systems
	Backup and disaster recovery	% of overall number of systems

Table 2 – Functional criteria for MEG level.

Level	EHR function (e.g., inpatient physician order entry)	Requirement
7	The system is able to share EHR data among hospitals; it can provide automated CDS based on the integrated data, such as duplicated therapy.	Core
6	The system provides an adverse drug event reporting function; when an order is placed, the system automatically checks clinical guidelines or pathways and provides feedback to clinicians.	Core
5	Orders are stored in a central data repository; the system can provide at least 4 types of CDS, including drug–allergy, drug–disease, drug–lab, drug–drug interaction alerts and other CDS	Core
4	Clinical decision support (CDS) is provided for order entries, such as drug–drug interaction alerts	Core
3	A physician order is transferred to the pharmacy department, nurses, and the billing department via a computer network; the physician can view the availability of the ordered medication in the pharmacy inventory; and the physician can view the brand or strength of the medication	Core
2	A physician order is transferred to nurses via a computer network	Core
1	An order is placed using an EHR system and can be shared by manually copying order files from one computer to another	Core
0	A physician places an order manually or using a standalone computer	Optional

Table 3 – Criteria for final MEG level and score.

Level	General description	Core functions	Optional functions[a]	Minimum total score[b]
7	Regional data sharing among hospitals	24	6/12	210
6	Close-loop data management for all processes, full EHR implementation, complex clinical decision support	24	6/13	170
5	Integrated clinical data management within hospital, data integration of all departmental systems	21	8/16	140
4	Patients data sharing within hospital, medium clinical decision support	19	8/18	120
3	Data sharing among departments, simple clinical decision support	18	8/19	85
2	Data sharing within a department	11	13/24	60
1	Data collection within a department	6	18/29	27
0	Manual process or standalone computer	–	–	–

[a] For example, "6/12" indicates that of 12 optional functions defined at level 7, the system must support at least 6 functions and the usage of these functions must be above 50%.
[b] The minimum scores of each level were specified by experts' opinion.

example, for the Inpatient Physician Order Entry function, it is optional for level 0 but it is core (required) for level 1–7. For each function, a score is calculated by multiplying the level of the function by its usage rate. For example, if the "Inpatient Physician Order Entry" function is graded at level 3 and the usage is 70%, then the score for this function is 2.1 ($3 \times 70\%$).

The overall MEG level for EHR adoption is assessed by the following three criteria: (1) it must support all core functions defined at that level and the usage of each core function must be above 80%; (2) it must support the minimum number of optional functions defined at that level and the usage of each optional function must be above 50%, and (3) the overall score, which is the sum of each function's score, must be greater than the minimum score defined at each MEG level. Table 3 shows the final overall MEG levels 0–7, its general description and the three criteria.

3.4. *Data collection*

Data collection started with release of a notification by the MOH requiring all tertiary hospitals in China to participate in the EHR adoption evaluation. Four required training workshops for Chief Information Officers (CIOs) and technical staff in tertiary hospitals were included in this notification with an expected completion date of October 2012. In total, 848 hospitals from 30 different provinces in China completed the data reporting, account for nearly 70% of all tertiary hospitals in China. Most tertiary hospitals (94%) included in this study were public hospitals. For various reasons, approximately 30% of tertiary hospitals did not comply and finish data reporting. Likely reasons were: (1) some hospitals do not have an EHR system, (2) data reporting was voluntarily and time-consuming, lowering the response rate, and (3) some hospitals did not receive the notification for training and data reporting of MEG due to the negligence of local heath authority.

Data was obtained from the NIHA online data center. A CIO or a technical staff member at each site was responsible for filling out and reporting the online MEG data from their respective hospital EHR to the NIHA. This data included functional capabilities according to the MEG criteria as well as hospital characteristics and IT investment, including: hospital region (east, central and west), bed size, number of beds per nursing unit, inpatient discharge, outpatient admission, total income in 2011, percent of IT investment per income in 2011, IT investment in last 3 years, number of IT staff, and duration of EHR use.

3.5. *Data analysis*

We assessed the MEG level of involved hospitals and calculated the average score of the 37 EHR functions. We then performed a multivariate analysis and a partial least squares (PLS) regression modeling method to explore influencing factors of total score and scores of 9 roles of involved hospitals. All hospital characteristics and IT investment were included in the model. A p-value of less than 0.05 was used to indicate statistical significance for variables in the model. We used IBM SPSS Statistics 19 to perform all our analyses.

4. Results

This study involved 848 hospitals distributed across 30 different provinces in China, as demonstrated in Fig. 1.

About half of respondent hospitals were from eastern China with the remaining half being equally split by central and western China. Hospitals were fairly large with over 1000 beds per hospital and 33 beds per nursing unit. On average, total hospital income was slightly over 500 million (Chinese Yuan) and just over 1% of income was invested into health IT (Table 4).

4.1. *Measurement of MEG*

When evaluating EHR adoption using MEG (Fig. 2), nearly thirty percent (30.7%) of the tertiary hospitals still have paper based or stand alone computer systems in place, while another 31.7% is at level 2. Less than 1% is at level 6 and none at 7.

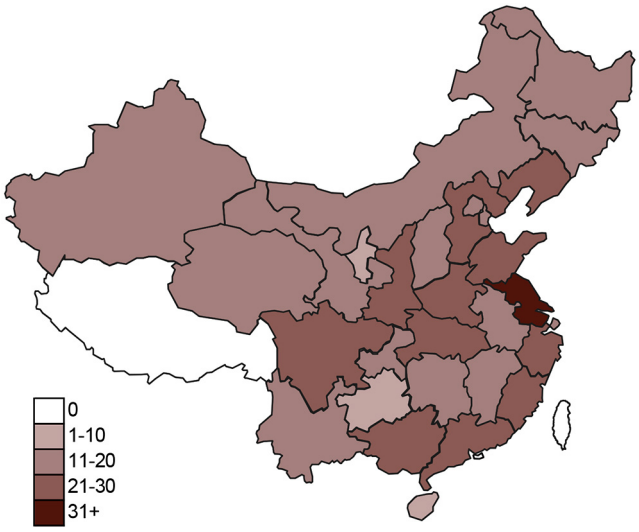

Fig. 1 – Numbers of participating hospitals per province.

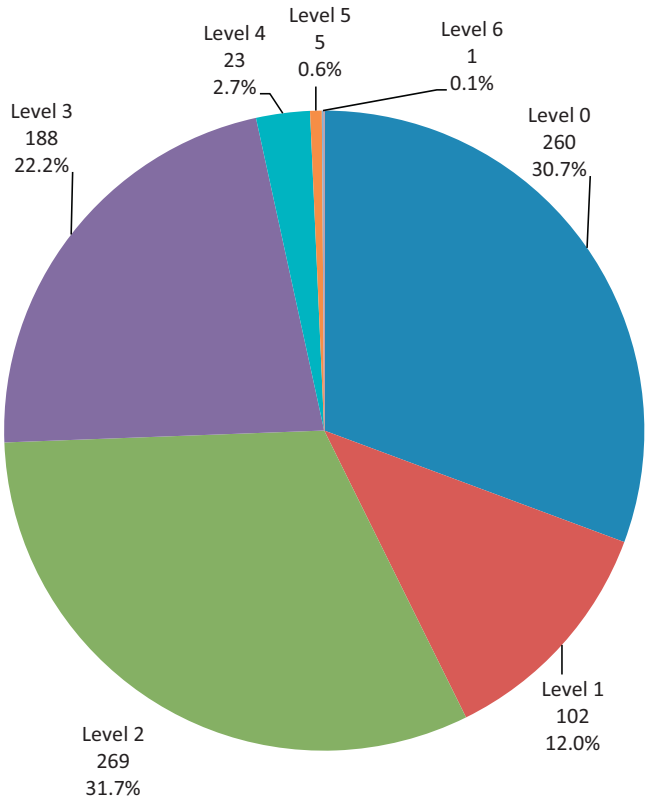

Fig. 2 – MEG Level of 848 hospitals.

Table 4 – Hospital characteristics and IT investment of investigated hospitals ($n = 848$).

Hospital characteristics	Percent/mean (count = 848)
Region	
East	48.47%
Middle	25.71%
West	25.83%
Bed size	1034.66
Beds per nursing unit	33.38
Inpatient discharges (Thousand)	9.18
Outpatient admissions (Thousand)	196.11
Total income in 2011 (Million Yuan)	521.64
Percent of IT investment per income in 2011	1.07%
IT Investment in last 3 years (Million Yuan)	11.15
Number of IT staff	7.14
Duration of EHR use (years)	7.00

In comparing EHRs functions using MEG (Table 5), computerized provider order entry (CPOE) scored the highest and included both inpatient/outpatient physician order entry and nursing order entry. The two lowest functions were the procedure and ICU roles, anesthesia and ICU records, respectively.

Our multivariate analysis (Table 6) showed that eastern hospitals demonstrated a higher score then central and western hospitals on all roles except for inpatient nurses. Western hospitals as compared to central hospitals, scored higher on all roles except for procedures and ICU, blood center and pharmacy, and records management – even when all other major organizational characteristics and IT investment were controlled.

Bed size, outpatient admission, total income in 2011, percent of IT investment per income in 2011, IT investment in last 3 years, number of IT staff, and duration of EHR use were all highly significant positive factors for total score with the latter five having greater influence on MEG score than other factors.

5. Discussion

MEG has been able to help assess the level of EHR adoption and functionality among tertiary hospitals across different regions in China and provides valuable insights for the appropriate direction for future EHR development in China as well as intra- and inter-hospital variability. We found nearly 30% of hospitals are still have paper-based or stand-alone computer systems while another 30% are at level 2. Less than 1% has level 6 and none have level 7. Eastern hospitals as compared to central and western hospitals demonstrated higher MEG scores and level of EHR adoption.

Similarities and differences exist between MEG and the HIMMS EMRAM models. For example, MEG and EMRAM, as well as a study by Jha's, each emphasize the functionality of EHRs and their usage [21]. In both MEG and EMRAM, these functionalities were graded in a similar fashion from "no system implemented" to "full EHRs implementation and health information exchange". Definitions of each level were also some similar. For example, EMRAM level 5 requires eMAR, bar coding or other auto-identification technology. In MEG, bar coding was a main requirement of the inpatient pharmacy function. In EMRAM, level 3 requires the first level of clinical decision support to conduct error checking with order entry. In MEG, inpatient physicians' order entry also requires at least one kind of error checking in order entry. Some of the differences noted were MEG measures EHRs according to workflow and roles, while EMRAM assess EHRs by systems.

Table 5 – Score of 37 functions.

Roles	Functions	Score	
		Means	SD
Inpatient physicians	Order entry	3.19	0.06
	Viewing laboratory reports	3.06	0.05
	Inpatient reports	2.86	0.06
	Viewing examination reports	2.63	0.06
	Laboratory test requests	2.62	0.05
	Examination requests	2.27	0.05
	Clinical decision support and knowledge bases	1.74	0.06
	Average of the role	2.62	0.05
Inpatient nurses	Order entry	3.47	0.05
	Patient assessment and management	3.18	0.06
	Nurse documents	1.97	0.06
	Average of the role	2.87	0.05
Outpatient physicians	Order entry	2.98	0.06
	Laboratory requests	2.81	0.05
	Viewing laboratory reports	2.79	0.05
	Examination requests	2.59	0.06
	Viewing examination reports	2.50	0.06
	Clinical decision support and knowledge bases	1.59	0.06
	Clinic visit notes	1.50	0.06
	Average of the role	2.40	0.05
Ancillary departments	Report generation	2.74	0.06
	Images	2.47	0.06
	Patient records	2.43	0.05
	Requests and appointments	2.41	0.05
	Average of the role	2.51	0.05
Laboratory	Report generation	3.22	0.06
	Result records	3.00	0.05
	Sample processing	2.97	0.05
	Average of the role	3.06	0.05
Procedures and ICU	Surgery scheduling, registration and records	2.30	0.05
	Procedure and treatment records	1.79	0.05
	ICU monitory data	1.33	0.05
	Anesthesia	1.10	0.05
	Average of the role	1.63	0.04
Blood center and pharmacy	Outpatient pharmacy	2.83	0.05
	Inpatient pharmacy	2.77	0.04
	Blood matching and use	2.00	0.06
	Blood preparation	1.98	0.05
	Average of the role	2.39	0.04
Records management	Quality control	2.79	0.06
EHR infrastructure	Data storage	3.62	0.06
	E-authentication and e-signature	2.73	0.06
	Data access control and auditing	2.59	0.06
	Backup and disaster recover	2.43	0.06
	Average of the role	2.84	0.05
Total score		93.24	1.55

Lastly, paperless workflow, a requirement of EMRAM, was not explicitly mentioned in MEG.

Although the grading criteria are not identical with those of EMRAM's, and the number and type of investigated hospitals are far from equal, the proportion of first time estimates of MEG (in 2011) and HIMSS EMRAM (in 2005) are quite similar. Most hospitals are among level 2 and 3 and higher level hospitals are rarely seen [25,26].

EHR functionalities that were comparatively strong were inpatient and outpatient CPOE, laboratory report generation and viewing, outpatient pharmacy, and radiology images and reports which is mirrored by the reality that CPOE is one of the most early and fully adopted modules in EHR construction in China, followed by Picture Archiving and Communication Systems (PACS) and Laboratory Information Systems (LIS). Those that were comparatively weak were anesthesia, ICU, clinic visit notes and nursing documentation. These likely reflect the difficulty in adopting and applying EHRs in these practice settings and are in accordance with a comparison survey performed in Australia and Germany, which showed a relatively

Table 6 – MEG total score and 9 roles' score according to hospital characteristics and IT investment.

Variables	Total Score	Inpatients physicians	Inpatient nurses	Outpatient physicians	Ancillary departments	Laboratory	Procedures and ICU	Blood center and pharmacy	Records management	EHR infrastructure
Region										
East	0.101*	0.085*	0.034	0.093*	0.098*	0.090*	0.118*	0.109*	0.085*	0.089*
Central	−0.082*	−0.083*	−0.073*	−0.080*	−0.090*	−0.116*	−0.030	−0.033	−0.012	−0.064*
West (as reference)										
Bed size	0.048*	0.033	0.050*	0.010	0.049*	0.064*	0.038	0.047**	0.059*	0.066*
Bed per nursing unit	0.071**	0.091*	0.028	0.076**	0.046	0.084*	0.043	0.070**	0.073**	0.043
Inpatient discharge	0.048	0.027	0.032	0.015	0.054**	0.046	0.053**	0.059**	0.073*	0.045**
Outpatient admission	0.068*	0.073*	0.055**	0.057**	0.051	0.079*	0.053	0.092*	0.015	0.024
Total income in 2011	0.070*	0.067*	0.036	0.079*	0.054**	0.044**	0.063*	0.075*	0.051**	0.037
Percent of IT investment per income in 2011	0.097*	0.060	0.122*	0.075*	0.083*	0.095*	0.117*	0.052	0.074*	0.137*
IT Investment in last 3 years	0.125*	0.120*	0.101*	0.122*	0.123*	0.079*	0.121*	0.104*	0.058	0.127*
Number of IT staff	0.156*	0.158*	0.142*	0.153*	0.138*	0.120*	0.125*	0.128*	0.142*	0.139*
Duration of EHR use	0.118*	0.125*	0.097*	0.123*	0.107*	0.113*	0.087*	0.105*	0.042	0.079*
R^2	0.286	0.258	0.174	0.229	0.239	0.232	0.216	0.258	0.154	0.206

* $p < 0.05$.
** $0.05 < p < 0.1$.

low adoption of anesthesia, ICU and outpatient and nursing records systems as compared to CPOE, laboratory and patient management systems [33].

The socio-economic gap between eastern and mid-western society is well known and similarly reflected in the healthcare industry [34–37]. Consequently, MEG scores for eastern hospitals were higher than those in central and western hospitals. Although the results of MEG were not included as an individual indicator in MOH's General Hospital Grading Program [38], the actual level of MEG appeared to be in accordance with the existing MOH certified grade result. The results of MEG also indicate that the gap in the whole healthcare industry may be enlarged with the development of HIT if there is no policy to support it. Governmental HIT promoting policy might be one of the most important considerations for policy makers in China for the promotion of EHR adoption.

As the development of hospital IT continues, MEG will play an increasing important role in the process of healthcare policy decision-making. A nationwide strategy that focuses more on policy incentives, for example, to honor the hospitals above level 5 annually and to include MEG as an individual indicator in MOH's General Hospital Grading Program may accelerate the validation and recognition of MEG. Financial investment is also a strong motivator for EHR adoption and a main policy choice for the government to stimulate hospitals' adoption of information technologies. Hospitals' investments in EHR adoption depend on financial income of themselves. It is not only the situation in private hospitals but also in public hospitals that are managed by the MOH or local health authorities. Although 7% of public tertiary hospitals' cost was reimbursed by government, there were no governmental financial stimulators in HIT until now [39]. Chinese governments should take more responsibility to lead the investment in HIT. Financial investment should be favorable to public hospitals, western and central area hospitals, and also to secondary and primary hospitals, which have lower incomes.

Currently, most hospitals use diverse commercial EHR products. These EHR products need a national-level certification which warrants its capability to ensure patient safety and quality of care. The establishment of the MEG model will promote HIT standards and data interoperability. HIT training is another urgent task with the lack of multi-disciplinary staffs and relative educational plans to organize training courses for CMIOs, IT staff, or clinicians. Seminars that focus on experience and lessons shared of the awarded hospitals will also be welcomed.

6. Challenges

We performed a series of on-site review for hospitals grading level 5 and above. During the on-site review, presidents, CIOs and technicians discovered several challenges that could limit the adoption and application of EHRs in China:

1. Inadequate government investment and inappropriate distribution of investment.
2. Lack of relative legislation for legal and safety issues of EHR.
3. Lack of standards and regulations.

Summary points
What was already known on the topic:

- EHRs have the potential to improve hospital efficiency and effectiveness.
- Studies have reported the state of EHRs adoption and use in several industrialized nations, including some Asian countries.
- There still lacks of reliable estimates of the prevalence of EHR use in Chinese hospitals.

What this study added to our knowledge:

- Model of EHRs functional grading, launched by MOH China, has examined levels of EHRs adoption in 178 Chinese hospitals.
- Most of the 848 hospitals have only a basic system around level 2 and 0, very few have a higher score.
- The EHRs adoption level for clinical information using and sharing are relatively low.
- Policy incentives and proper evaluation could increase the prevalence of EHRs adoption in Chinese hospitals.

7. Study limitations

This estimate focused on EHR adoption and application. It lacked a variety of variables that may be of interest. For example, indicators to automatically extract data from EHRs for clinical quality and safety evaluation, lack of management functions, and satisfaction of EHR users. In addition, only tertiary hospitals were included in this study and the sample does not represent all hospitals in the country, future studies will extend to secondary and primary hospitals.

8. Conclusion

We examined levels of EHR adoption in 848 Chinese hospitals and found that most of them have only basic systems, around level 2 and 0. Very few have a higher score and level for clinical information using and sharing.

Authors' contributions

Minghui Liang, Haiyi Liu, Ting Shu contributed for the research design, data acquisition and analysis. Ting Shu, Wei Yang contributed for the data acquisition and analysis, and manuscript writing. Foster R. Goss contributed to the manuscript writing and editing. Li Zhou and David W. Bates participated in data interpretation and helped to draft and revise the manuscript.

Competing interests

None.

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