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Electronic Health Record (EHR) System for Developing as well as Developed Countries Based on the openEHR Approach

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This paper describes first the significance and current situation regarding the Electronic Health Record (EHR) systems and recent developments toward the EHR standardization. Then introduction is made of the openEHR approach, which has emerged in Europe and now gaining wide acceptance and support on a global basis. The openEHR approach has been also considered by the author and his research group as a sound basis for developing an EHR system for its architecture and openness. This paper also includes descriptions of four EHR systems developed by our group and concludes that the openEHR approach is powerful and effective to produce EHR systems that are interoperable with each other.

1. Introduction

Use of computers is penetrating into a wide variety of aspects in our life and of industrial sectors, including the healthcare sector. However, when it comes to the networking of computers, *i.e.* information networking, the healthcare sector is one of the least networked sectors, which is causing a number of problems, which could be solved by information networking. The problems include, among others, lack of health information sharing among healthcare institutions, which leads to the duplication of medical checks and thus increased medical expenditure, and lack of sufficient evidences for a medical diagnosis and treatment. Against this trend, the so-called health informatics academic discipline is now gaining momentum in healthcare sector from both academic and practical points of view.

This paper introduces new trend in health informatics, represented by the openEHR initiative, and describes its significance and impact on current healthcare sector. One of its significance is the standardization of Electronic Health Record (EHR) systems, aiming at achieving the semantic interoperability, which means that the EHR systems installed from different vendors in different healthcare institutions can exchange information in a semantically meaningful way. Another significant point lies in the introduction of open source software concepts into health informatics industrial sector, which is expected to reduce the cost of developing an Electronic Health Record (EHR) system and to create an "eco-system" in the EHR industrial sector. The introduction of open source software, which means that the produced software packages classified as open source software are made available through the internet for use and further modifications, if needed, either free of charge or by paying a reasonable fee. This will facilitate

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the development and introduction of EHR systems because software products classified as open source can be reused or modified, thus pushing down the cost of developing an EHR system for use both in developed and developing countries.

Another important point of this paper is the results of openEHR related studies performed for developing countries by master students at Waseda University under my supervision. They include the development of EHR systems for Japanese metabolic syndrome test results, Indonesian emergency medical services, Cambodian tuberculosis data collection and maternity care. These results will benefit both developed and developing countries, as they offer evidence that the openEHR approach has a global applicability, thus will benefit the developed countries as well.

2. Electronic Health Record (EHR) system—its significance

The Electronic Health Record (EHR) is a record which contains a person's health record, and forms a core of the health information networking as it is that which is exchanged through the health information network. The significance of EHR systems can be enumerated as follows:

1) For the healthcare professionals, the EHR systems allow the sharing of person's healthcare information, for example, who is suffering from similar symptoms and/or similar diseases. It will be a key to realize the so-called Evidence Based Medicine (EBM) by collecting related information widely throughout a large number of healthcare institutions. With the use of current non-standardized paper health records, it is not easy to collect a sufficient amount of information to validate certain diagnosis and/or treatment.

2) For the patients, since it would become easy for healthcare institutions to share a person's past healthcare records, duplication of expensive tests such as blood testing, Computerized Tomography (CT) imaging can be avoided, it would be easier for them to visit a new hospital or clinic for various reasons, for example, people travelling or living in a foreign country to visit a local hospital or clinic.

3) For healthcare institutions, the introduction of EHR systems will make their activities much more efficient and accurate as a result of replacement of current paper health records by computers. This will result in the reduction of back office staff, who is involved in the transfer of order information from doctors to nurses and radiologists, and in billing, to name a few supporting works of a healthcare institution. It is estimated that this and the fore-mentioned reduction of duplication will reduce the current sky-rocketing medical expenditures. Because of these reasons, introduction of EHR systems into healthcare institutions is becoming a high priority item in many country's political agenda, including Japan, USA and UK.

3. Electronic Health Record—current status

The use of EHR Systems by healthcare institutions is currently very limited in most of the developed countries, except in Scandinavian countries, as shown in Table 1. For example, in Japan, only 10% of primary care physicians and hospitals were equipped with EHR systems in 2006. This low rate of penetration of EHR systems in most of the developed countries can be ascribed mainly to two reasons:

1) The lack of global standards for EHR; and

Table 1. Use of EHR Systems by Countries as of 2006[1]

Country	By Primary Care Physicians (%)	In Hospitals (%)
Australia	79	<10
Canada	23	<10
Finland	99	100
Germany	42	<5
Japan	10	10
The Netherlands	98	<5
Sweden	100	88
United States of America	28	8

Source: David Castro "Explaining IT Applications Leadership—Health IT", The Information Technologies & Innovation Foundation, September 2009

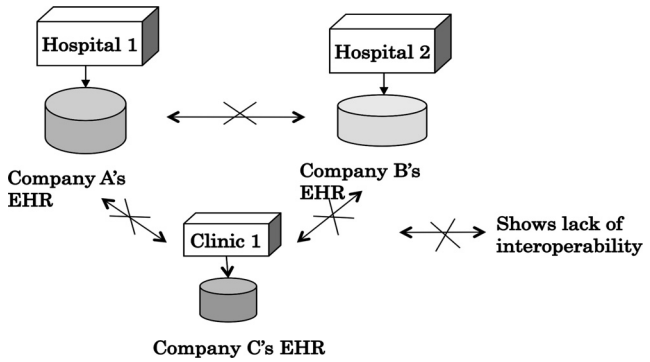


Fig. 1. Current Business Model of proprietary EHR systems which are not interoperable

2) The resulting extremely costly EHR systems, in particular, for small to medium hospitals and for clinics.

Due to the lack of global standards for EHR, currently, each of the EHR system developers manufactures its own proprietary EHR systems, and when a healthcare institution such as a hospital introduces an EHR system into it, the hospital is "locked in" to the proprietary systems of that manufacturer. This leads to the existence of a number of isolated EHR systems in multiple hospitals that cannot interoperate with one another, as shown in Fig. 1. This results in the following demerits:

1) EHRs stored in proprietary systems are not interoperable, thus defeating one of the important EHR objectives, *i.e.* information sharing among multiple healthcare institutions;

2) Overlapping development efforts are needed among multiple EHR system developers, resulting in costly and slow development.

4. New developments towards EHR standardization

In the presence of these demerits, standardization efforts have started in USA (HL7)[2] and in Europe (openEHR)[3]. HL7 stands for Health Level 7, Level 7 referring to the application layer in the ISO's OSI (Open Systems Interconnection) reference model. HL7's efforts are aimed at defining messages that are exchanged between two EHR systems. On the other hand, openEHR has defined Archetypes, which are precise

definitions of standardized medical concepts to build an EHR, to achieve the semantic interoperability. In studying both of them, our conclusion was that we should adopt and follow the openEHR approach for the following reasons:

1) While HL7 defines messages to be exchanged between EHR systems, these definitions are not sufficient to achieve the semantic interoperability unless the medical concepts used in these messages are precisely defined and standardized.

2) The openEHR has a layered hierarchical architecture with modular structure, which facilitates the separation of medical expertise and IT expertise. Therefore, medical professionals and IT professionals can cooperate in a harmonious and efficient way.

3) The openEHR approach is based on the "open" source concept, which makes available the use of software source codes either free of charge or with a reasonable fee. This is especially important for developing countries, where resources are scarce.

4) Because of the above 2) and 3), the openEHR would lead to the creation of an "EHR eco-system", where parties involved would share a symbiotic and evolutionary process together.

5. The openEHR architecture[4]

One of the most important architectural concepts of the openEHR approach is first the definition of Archetypes, which are used as building blocks to construct Templates for different purposes of EHRs as a combination of Archetypes. Figure 2 illustrates this architecture. It is composed of 3 layers: the basic layer is a repository of "Archetypes", each of which constitutes a precise definition of medical concepts that are universally accepted. The middle layer is composed of "Templates", each of which is a form into which medical information will be inserted, *e.g.* on a per medical department basis.

The top layer is composed of EHRs where actual patients' health information is stored.

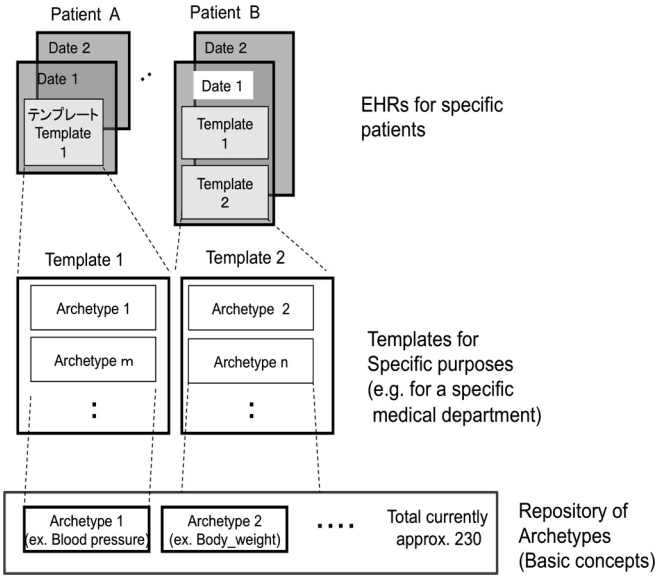


Fig. 2. Three layered openEHR architecture overview

6. The openEHR, its brief history and current organization[5]

The openEHR initiative had been started by medical doctors who were not satisfied with the then proprietary electronic health records in early 1990s at University College London (UCL). They include names such as Dr. Sam Heard, Dr. David Ingram and Dr. Dipak Karla. They arrived at the concept of "Archetypes"around 1996.

According to Dr. Sam Heard, there were two major problems with the EHRs in the 1990s[6].

1) Message formats were not standardized to exchange medical information. There is a need for standardized communication message formats and protocols to exchange them. Solving this aspect of the problem was considered as the job of IT engineers.

2) Even within one company's EHR, the semantics (meaning) of medical information items were not precisely defined. There was a need for precisely defined medical concepts to make sure that the semantic interoperability is achieved. This aspect of the problem was considered to be the job of medical professionals.

The openEHR initiative derives its origin from the Good European Health Record (GEHR) project established in 1989. Then after a series of endeavors to develop appropriate models and methodologies, the openEHR Foundation was established through 1998 to 2001, in UK and Australia, with the following aims and principles[7].

- be open to all who sign up to its objectives and methods of work
- have free individual membership
- help to define and support a common process of specification of clinical requirements, specification and implementation of systems and evaluation of the electronic healthcare records provided
- offer the sources of such systems, in which IPR (Intellectual Property Right) will be assigned to open EHR, under an open-source license within the community.
- offer all its work openly in a spirit of a public enterprise, believing that this is the best and perhaps only way that appropriate high quality and interoperable systems are likely to emerge, worldwide.
- seek constructive relationships with groups and communities focusing on other aspects of clinical information management such as messages, terminology, knowledge-management and decision-support.

The openEHR was adopted as an International Standard (ISO13606) by ISO (International Standards Organization) in 2008. As of summer 2010, it is used in Europe (UK, The Netherlands, Spain, Sweden, *etc.*) and in Australia and attracting the attention and research and development efforts in Japan, Canada and USA. Microsoft announced that it would adopt the Archetypes in their Connected Health Framework (CHF) V.2 in 2009.

7. Achievements at Waseda University under Professor KANO Sadahiko

7.1 Introduction

The author started to study about the EHR systems around year 2000. Initially, we (Professor Kano and his graduate students and a visiting researcher) studied the Health Level 7 (HL7) activities. Some graduate students as well as a visiting researcher participated in HL7 meetings held in USA. However, we encountered difficulties in understanding its architecture, *i.e.* its hierarchical and modular structure.

We then started to look at the openEHR initiative in parallel, and in 2007, a graduate student did an intern work at Ocean Informatics in Australia, which was the leading software house in the openEHR initiative. Since the return of the intern student, our knowledge on openEHR has been deepened. In January 2009, an academic license to use the Ocean Informatics' Template Designer was obtained. Since then, following students produced EHR systems for their respective purposes:

- Nora Hsu (graduate student from Taiwan) produced an EHR system for the Metabolic Health Check in Japan (January 2009);
- Yunan Satria (graduate student from Indonesia) produced an EHR system for emergency medical services for use in Jakarta, Indonesia (July 2009);
- Kong Saran (graduate student from Cambodia) produced an EHR system for the collection of tuberculosis patients data for the Ministry of Health in Cambodia (July 2010);
- Hok Kakada (graduate student from Cambodia) produced an EHR system for the maternal care at the National Maternal and Child Health Center in Phnom Penh City, Cambodia (July 2010).

7.2 EHR system for metabolic health check by a Taiwanese student[8]

Nora Hsu, a graduate student from Taiwan, created an EHR system for metabolic health check, which was started in Japan in 2008. Her EHR system was test-used by a practicing nurse, who was also healthcare consultant as well as doctor course student at a medical university. Her response was as follows:

1. She was impressed with the flexibility in the openEHR architecture provided

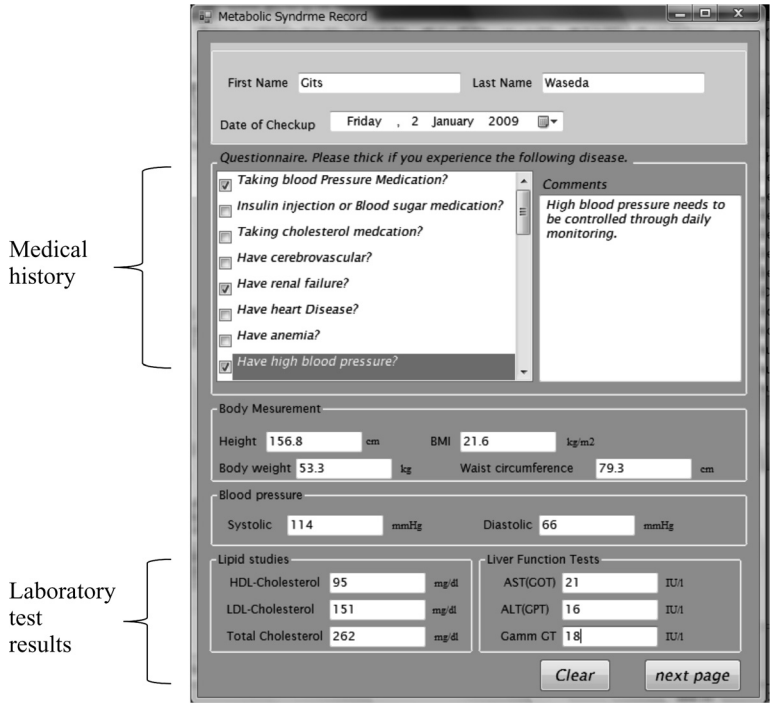


Fig. 3. A screenshot of an EHR for metabolic syndrome check in Japan

by the separation of medical domain and software domain.

2. She was also impressed by the openness and potential interoperability of openEHR architecture.
3. She said that there were already several proprietary implementations of metabolic syndrome test results. They were not interoperable and this would create a big problem in the future.

Figure 3 shows a screenshot of Nora Hsu's EHR for metabolic syndrome check in Japan.

7.3 EHR system for emergency medical services by an Indonesian student[9]

Yunan Satria, a graduate student from Indonesia, and his elder sister, who is a medical doctor in Indonesia, created a private medical emergency service company in Jakarta, after the sudden death of their father by heart attack. The public emergency medical service in Jakarta had been so poor, otherwise their father could have been saved from his heart attack. This was the motivation for them to start a venture private emergency service in Jakarta.

In order to avoid traffic congestion on the roads of Jakarta, emergency paramedic squad members usually go to the rescue spot by motorcycles. So, mobile handsets rather than a PC (Personal Computer) are always carried by them. Hence implementing an EHR system that can be used by a mobile handset is essential, besides the regular PC, which would be used by a medical doctor at the Emergency Health Center.

He has succeeded in implementing a platform independent EHR system by using the Java programming language and its supporting development tools, called the Java Development Kit (JDK). Platform independence means that the EHR system he has produced can run on any type of computer operating system (OS), be it an OS for a PC or an OS for mobile handset. Figure 4 shows screenshots of his EHR on PC, and handheld mobile terminals, in this case, iPod Touch and Blackberry.

The developed EHR system for emergency medical services was test-used by paramedics using handheld mobile terminals, and an emergency medical doctor, using PC at Emergency Health Center in Jakarta, while they were connected to the wireless internet in Jakarta through the global internet to the server PC located in a room of Waseda University, where Yunan Satria worked. Figure 5 shows the overall system structure.

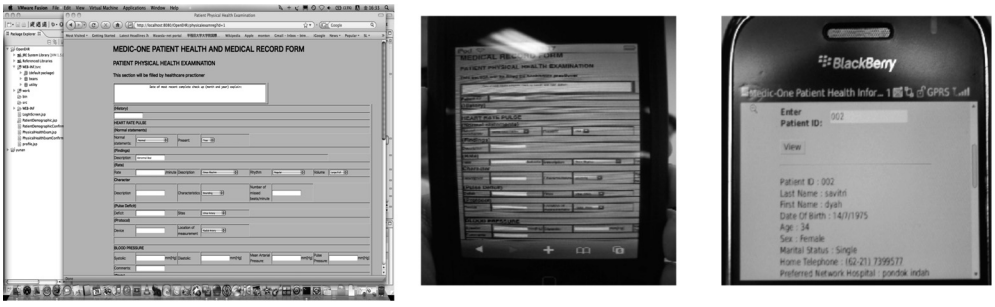


Fig. 4. Platform independent EHR for emergency medical services

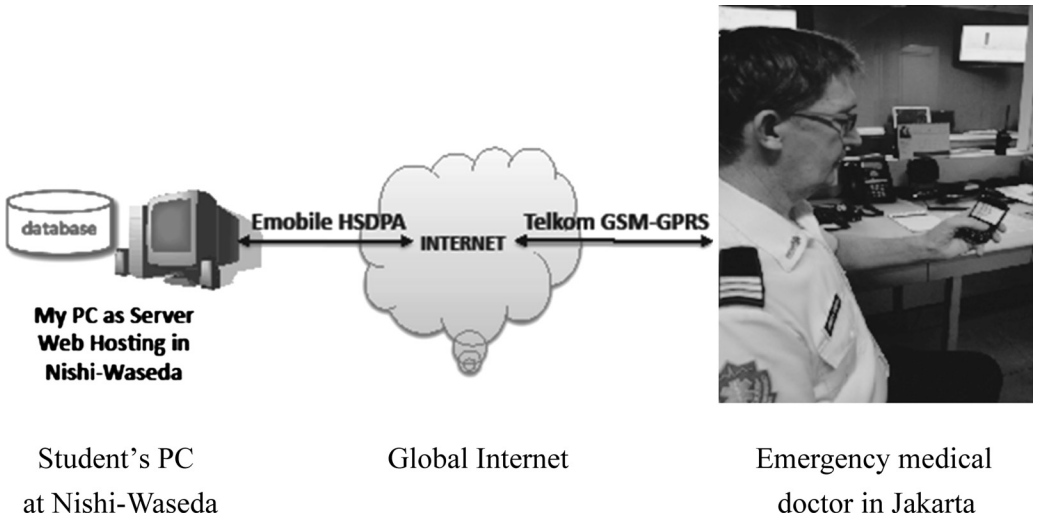


Fig. 5. Experimental network linking Mobile Terminal in Jakarta and student's PC at Nishi-Waseda through the global internet

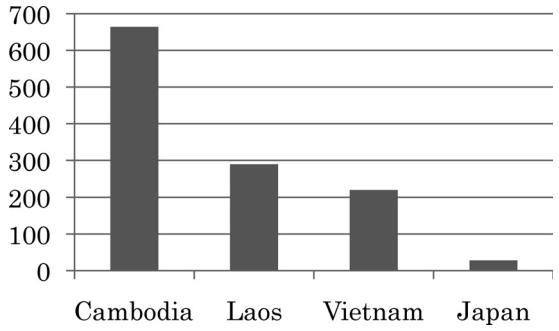


Fig. 6. Prevalence of Tuberculosis per 100,000 population (2007)[10]
Source: Compiled from World Health Statistic 2009, WHO

7.4 EHR system for tuberculosis patient data collection in Cambodia

Cambodia's top 3 causes of death are tuberculosis (TB), maternal complications at the time of baby delivery and AIDS. Regarding the tuberculosis, Cambodian situation is worse than its neighboring developing countries such as Laos and Vietnam, as shown in Fig. 6.

Cambodian Ministry of Health (MoH) is fighting against this situation by adopting the DOTS (Directly Observed Treatment, Short Course), which had been recommended by WHO. In order to efficiently apply this DOTS in the whole country in a balanced way, the MoH is currently collecting tuberculosis patient health record on paper from about 1,000 Health Centers scattered all over Cambodia. This process takes time and is prone to errors in handling handwritten data and during the paper collection and transmission. The purpose of our study to provide an EHR system for collecting tuberculosis data electronically is to improve this health record collection and provision of statistical data by replacing current paper records by computers.

The resulting computer input screen which replaces the current record is shown in

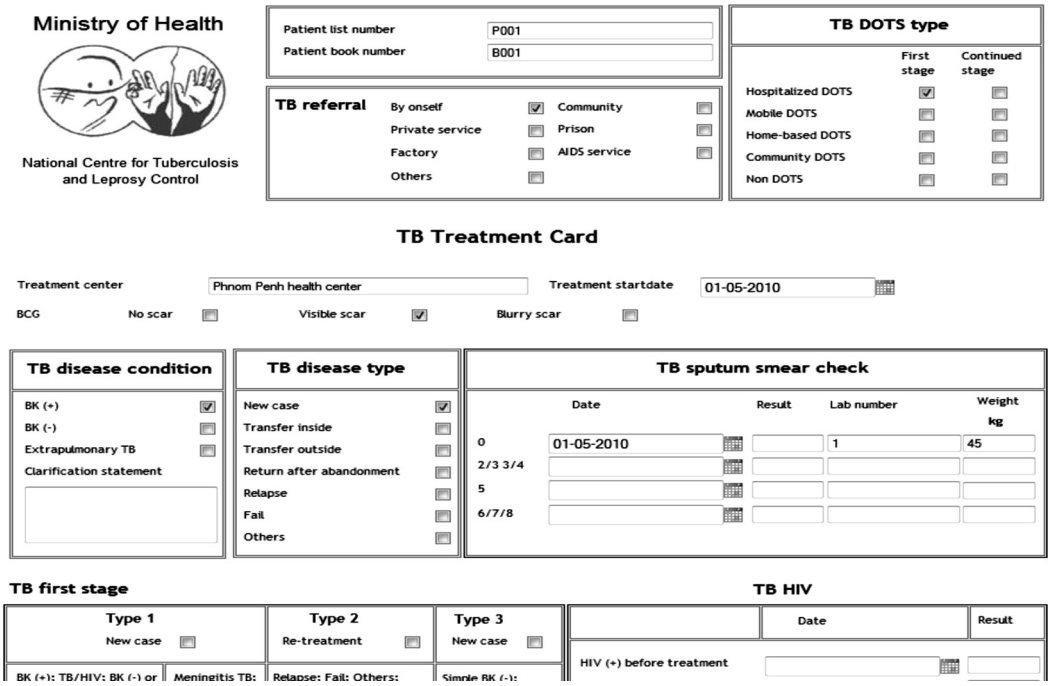


Fig. 7. Tuberculosis patient health record screenshot for data input[11]

Fig. 7. This input screen is designed to look similar to the paper form to ease the introduction of this system for the traditional Health Center staff. The information input on this screen is then converted into an openEHR Template composed of standard openEHR Archetypes.

In June 2010, this EHR system was demonstrated to the staff of the Cambodian Ministry of Health (MoH) in Phnom Penh, and some interesting and positive feedbacks were given by them. The MoH has a desire to introduce a national EHR standard and it is currently seeking partnership to assist it financially and technically.

7.5 EHR system for maternal care for use in Cambodia[12]

Figure 8 shows the comparison of maternal mortality ratio among Cambodia and other neighboring developing countries as well as Japan. The Figure shows that Cambodian maternal mortality ratio is significantly higher than its neighboring countries such as Thai and Vietnam, not to speak of Japan. On this point again, the Ministry of Health in Cambodia is making efforts to improve it.

Japan has been helping Cambodia to fight against this high maternal mortality ratio by introducing the use of maternal handbook（母子健康手帳）to pregnant women and by assisting to build a maternal care hospital in Phnom Penh, by the name of the National Maternal and Child Health Center (NMCHC). This hospital is called by native Phnom Penh people as the “Japan Hospital”. Currently, the NMCHC has about 150 pregnant women per day, and uses paper patient records for them, which are stacked on book-shelves, as shown in Fig. 9.

An EHR system is expected to enhance the speed and accuracy, as well as the efficiency of treating them. In designing an EHR system, first a study has been made on

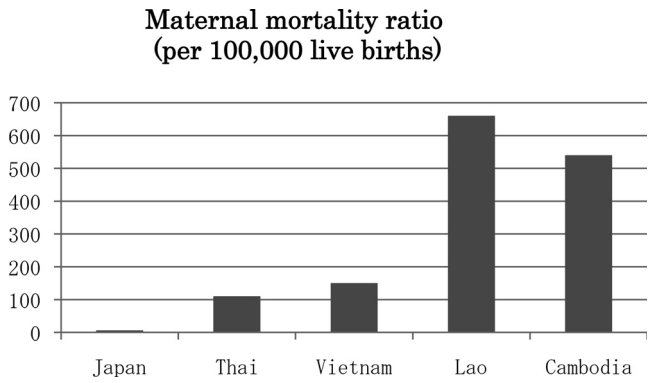


Fig. 8. Comparison of maternal mortality ratio among Cambodia and its neighboring countries (2007)[13]
Source: Compiled from "World Health Statistic 2009", WHO

Fig. 9. Current paper based patient health record stored on book-shelves at the NMCHC[14]

information flow and information items on the paper records and to compare them with the openEHR Archetypes already defined in the official openEHR Archetype Repository. The study led to identify the following 4 pregnancy care steps and, for each step, the following findings were made as to the usability of existing Archetypes:

Step 1: First visit—The existing Archetype "Evaluation_pregnancy" was found as not having all the needed information items for the first visit, leading to the new definition of an Archetype "Observation_pregnancy_first_visit".

Step 2: Uterus Examination—The existing Archetype "Evaluation_pregnancy" was found to be sufficient for this step.

Step 3: Delivery—The existing Archetype "Evaluation_pregnancy" was found that it did not contain the length, the chest circumference and the head circumference of the fetus. Therefore, these parameters were added to the existing Archetype "Evaluation_pregnancy (specialized)".

Step 4: Post natal care—Currently existing four Archetypes were found applicable. However, they did not include post natal mother's condition such as affection status of a disease, breast-feeding possibility and baby's condition. Therefore, a new Archetype "Post natal maternity" was created. Using these existing and newly created Archetypes,

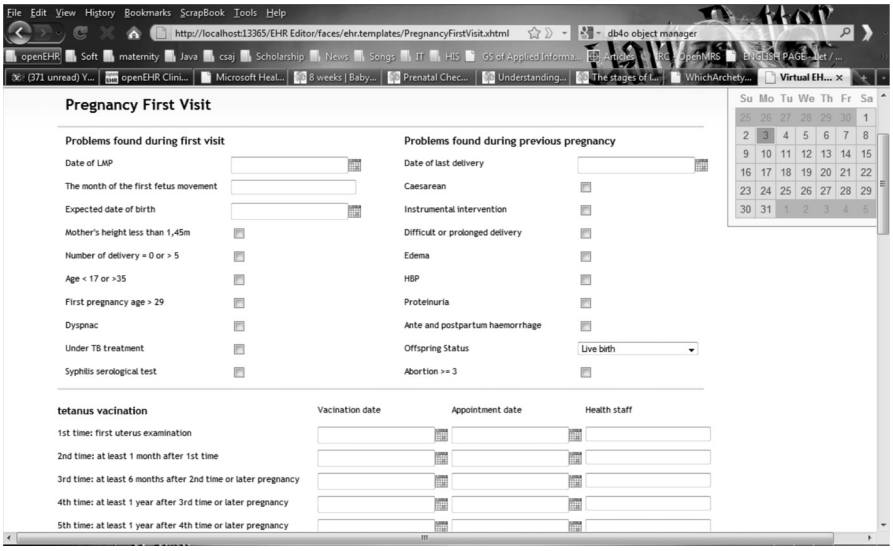


Fig. 10. Screen shot of the Template for the Maternity First Visit

the Templates have been created for each step. Figure 10 shows the screen shot of the newly created Template for the 1st step "Maternity First Visit".

The EHR system for maternity care had been demonstrated in June 2010 to the staff of the NMCHC in Phnom Penh and received feedbacks as follows:

- Positive feedbacks are the following:
  - — Patient demographic data is entered only once at Admission office, which, under current procedure based on the paper records, must be hand-written several times;
  - — The data is saved directly to a demographic database server, and can be retrieved easily later;
  - — All past medical records of a patient can be retrieved and listed in time order;
  - — The EHR system is flexible enough to accommodate ever changing health parameters;
  - — In future, it can be extensible to other departments such as Gynecology in the NMCHC;
  - — Though computer literacy is still low among the NMCHC staff, Deputy Chief of Technical Bureau was sure that he could train his staff and they will catch up quickly.
- Negative feedback received was as follows:
  The NMCHC does not have enough budget to implement this system. It would like to call for financial assistance from outside, *e.g.* from JICA which had kindly supported to build the Center.

7.6 Overall review of the openEHR approach

In addition to the specific points described so far regarding the respective EHR systems, the evaluation on the openEHR approach could be summarized as follows:

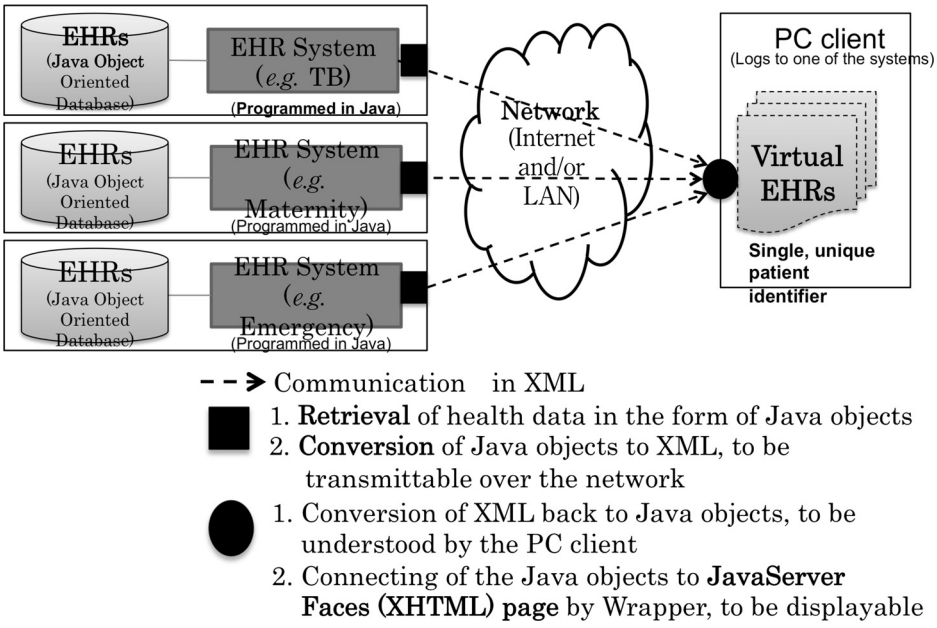
Merits:

1. Separation between medical and IT domains

The openEHR architecture which separates the expertise between medical professionals and IT engineers through hierarchical and modular structure has been proved to be extremely effective and useful. This separation has been achieved by concentrating medical knowledge in the Archetypes. This enables IT engineers to learn quickly about the openEHR approach and start implementing EHR systems in a short time. For example, four IT engineer master students described above could master the openEHR approach within 3 to 6 months, and have produced the EHR systems within one year including the 3 to 6 months learning period. All of their EHR systems had been evaluated by professional medical staff, and received positive feedbacks.

2. Use of open source software

Another reason why IT engineers (in this case, the master students) produced so quickly their respective EHR systems was the re-use of open source software packages that were available to them through the internet. Furthermore, all of the software packages used except one, *i.e.* Template Designer, were free of charge, leading to the minimum cost of developing them. This is a proof that (a) it helps developing countries to introduce EHR systems in their medical facilities, and (b) even for medical facilities in developed countries, the adoption of EHR systems would cost much less than the current closed proprietary EHR systems, in particular, for small to medium sized hospitals and clinics, which were reluctant to introduce EHR systems so far because of the high cost of investment needed.



Note: All of the above functions are contained in the Java tool called REST (REpresentational State Transfer) web service

Fig. 11. Virtual Editor to collect EHRs of a single person in multiple EHR systems via the Internet and LAN

3. Virtual EHR Editor

In addition to developing EHR systems for respective purposes, we have developed the Virtual EHR Editor, which can extract EHRs of a specific person which reside in multiple EHR systems. This assumes a single unique person identifier, which is already implemented in some countries such as Korea, Taiwan and USA (in the form of Social Security Identification Number), and under discussion currently in Japan. The Virtual EHR Editor we have developed assumes the use of open source Java programming language and associated Java-based tools as shown in Fig. 11.

Further study items:

Recognizing the issues concerning the EHR systems and the realities of current EHR business, we know that the following points require further study in order to be used as a full-fledged EHR system for a hospital:

1. Security, in particular, access control function
   Our EHR systems implement the most basic encryption-decryption and a very simple role based access control.
2. Managing functions to run a real hospital, such as billing, patient registration, medication management, inpatient management and logistics management.
3. Multimedia functions, *e.g.* interconnection with PACS (Picture Archiving and Communication System) which stores, *e.g.* X-ray images and CT images.
4. Various support tools used in hospitals, *e.g.* to extract data for various statistics to manage a hospital, or to be used for Evidence Based Medicine.
5. Business models based on the use of open source software, so that people involved in producing open source software EHR systems can get some revenue for their own living and for further investment in new projects.

8. Conclusion

This paper has shown that the openEHR approach has a potential to pave the way for worldwide health information networking which would bring a number of significant merits to improve the world's health as well as to reduce the current exploding medical expenditures around the world. Especially important is the fact that, thanks to the openEHR architecture which separates the expertise of medical professionals and IT engineers, the making of EHR systems has been significantly facilitated. However, further study is needed to develop a practical EHR system that can be used in hospitals, other healthcare institutions, and by individual people.

Last but not least, I would like to thank Dr. Sam Heard, one of the Founders and Board of Directors of the openEHR Foundation, for his advices in performing our study and also the four then master students under my supervision, Nora Hsu, Yunan Satria, Kong Saran and Hok Kakada, who worked so hard and made efforts to study openEHR and to produce their respective EHR systems. Without them and their works, I would not have been able to obtain confidence in openEHR as I have now.

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