J Med Syst
DOI 10.1007/s10916-011-9688-z

ORIGINAL PAPER

Development of Fundamental Infrastructure for Nationwide EHR in Japan

Tadamasa Takemura · Kenji Araki · Kenji Arita · Toshiaki Suzuki · Kazuya Okamoto · Naoto Kume · Tomohiro Kuroda · Akira Takada · Hiroyuki Yoshihara

Received: 4 November 2010 / Accepted: 15 March 2011

Abstract The movement of create medical information systems that is now taking place involves both progress in EMR (Electronic Medical Records)—computerization of records at hospitals and clinics, and also in EHR (Electronic Health Records) in which information is shared with individual regions. However, the geographical coming and going of people in modern society is extremely active. Naturally the places these people move to are not necessarily within the same region. For this reason, even if the basic unit for the health care supply system is in practical terms limited to the local level, if services are restricted to only one region, many persons may be unable to receive the benefits of health care cooperation. In this study, we constructed a mechanism for a medical cooperation system which links the EHR systems of individual regions and is able to create a one-patient, one-record system on the national level. In this paper, we will provide a report of this mechanism and of the 4-year operational trial.

T. Takemura (✉) · K. Okamoto · N. Kume · T. Kuroda · H. Yoshihara
Department of Medical Informatics, Kyoto University Hospital, Kyoto, Japan
e-mail: takemura@kuhp.kyoto-u.ac.jp

K. Araki · K. Arita
Department of Medical Informatics, University of Miyazaki Hospital,
Miyazaki, Japan

T. Suzuki
Japan DynaSystems Inc.,
Nagoya, Japan

A. Takada
National Cerebral and Cardiovascular Center,
Suita, Japan

Published online: 01 April 2011

Keywords Nation level EHR · Dolphin Project · XML data mapping · Directory service

Introduction

The movement of create medical information systems that is now taking place involves both progress in EMR (Electronic Medical Records) computerization of records at hospitals and clinics, and also in EHR (Electronic Health Records) in which information is shared with individual regions. A variety of trials have been carried out worldwide for this purpose, primarily in developed countries, and informatics is also receiving attention as an effective means of improving the efficiency of medical services in newly industrialized and developing countries as well. For example under the leadership of the state, Canada and England have invested at least 1.6 billion U.S. dollars [1] and 20 billion U.S. dollars [2] respectively. It is said that the United States will invest 20 billion U.S. dollars in switching to electronic medical documents. For EHR, many successful examples in sharing medical information within regions continue to be reported from around the world, and several EHR projects have been carried out in Japan as well [3].

However the geographical coming and going of people in modern society is extremely active. In the United States, 35 million people change their place of residence each year [4], and it is said that on average a person in Japan moves 5 times in his or her life [5]. Naturally the places these people move to are not necessarily within the same region. For this reason, even if the basic unit for the health care supply system is in practical terms limited to the local level, if services are restricted to only one region, many persons may be unable to receive the benefits of health care

cooperation. In this study, we constructed the actual fundamental infrastructure needed for local medical EHR, and carried out EHR projects in several regions of Japan [6], and during this study we found that it will be impossible to gain a comprehensive grasp of patient medical information at the national level only because no solution to the problems caused by movement of patients. Of course, we cannot use national identified number in Japan, so it make the solving problems more difficult.

Therefore when considering the future development of EHR, a mechanism for consolidating local-level medical information on the national level, as well as functions for data compatibility and other purposes, will be needed.

In this study, we constructed a mechanism for a medical cooperation system which links the EHR systems of individual regions and is able to create a one-patient, one-record system on the national level. In this paper, we will provide a report of this mechanism and of the 4-year operational trial.

Methods

As we discuss a mechanism for medical cooperation between regions, we will first describe the current conditions of inter-regional medical cooperation in Japan.

Local-level EHR

Many regions in the world have created EHR systems for managing patient medical data within that region, and many projects have been launched using these systems as hubs for coordinated health care and the provision of medical record [1, 7, 8]. For these purposes, it is necessary to ensure safe routes of information between the medical institutions and the system, and also to create a mechanism that allows patients to safely view medical data via the internet, which penetration rate is 78.0% in Japan [9]. The formulation and operation of an open standard for exchanging medical data from a wide variety of medical records are also important [10]. In Japan as well, there are many EHR systems operating in individual regions. In these cases, the systems are operated in a way that makes best use of the unique characteristics of each region. Data exchange is accomplished in a variety of ways, including direct connections to the hospital information systems of large scale hospitals, and exchange using MML (Medical Markup Language) [11, 12] or HL7 (Health Level 7) [13]. Because it is the local governments which are directly faced with a need for health care cooperation in the region, in many cases the systems are operated under the leadership of the local governments, and currently it is difficult to carry out activities that span multiple regions.

Construction of a mechanism for wide-area medical cooperation

As described above, attempts to integrate local EHR systems and carry out services over a wide area face a number of problems. One is data-level integration. Although some believe that collecting data using a single unified format is sufficient, this approach is not practical when one considers the current conditions in which many independent local EHR systems are operating, using various formats. The solution is data conversion (mapping) on the content level between different data structures.

Another problem is fragmentation among EHRs because of lack of national level patient's identification. It is thought that this problem can be resolved by assigning an internal upper-level ID at upper-level sites in place of the unique IDs used on the local level, and to assign the local IDs to these upper-level IDs (essentially assigning them to an upper-level directory structure) [14]. Following is a description of data mapping and the upper-level directory structure.

Data mapping

Absorbing differences in data structures can be accomplished by constructing a mechanism for XML (eXtensible Markup Language) data mapping. Figure 1 shows a concept diagram of XML data mapping. A document has a format showed in the left-hand side while another document has a format showed in the right-hand side. For example, the document on the left-hand side in Fig. 1 defines the patient ID as <ID>, while the document on the right-hand side defines it as <SocNum>. If these two are considered equivalent, they can be mapped so that they can be converted back and forth. In the same way, <given name> and <first name> is another example that is often seen. If the XML label and the data indicated by that label have the same code system, they can also be mapped. For example, if <disease> in the left-hand document contains an ICD-10 code, then it can be converted to the <ICD code> in the right-hand document.

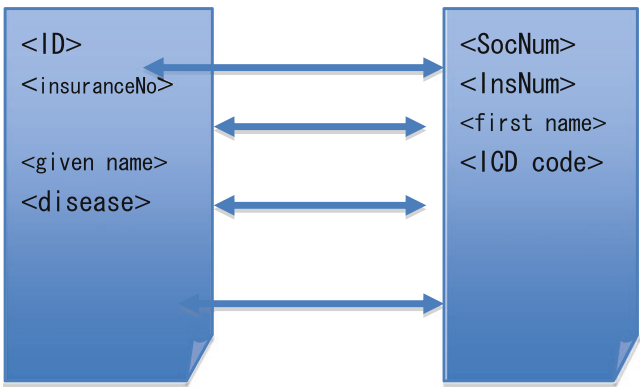


Fig. 1 XML data mapping

There have been reports of cases in which XML data mapping is used for bidirectional data conversion between EMR and EHR [15], and commercially products such as Asteria from the Infoteria Corporation (Japan) [16] and Rhapsody™ from Orion Health (New Zealand) [17] have been marketed as middleware intended for medical use. Use of these sorts of products makes data compatibility possible.

Upper-level directory structure

On the national level, if it is possible to issue and use a unique patient ID to each citizen on the national level, then such IDs can be used. However in many countries including Japan, use of these IDs in EHR is difficult. If a person is issued different patient IDs by multiple local EHR systems, it is necessary to understand that these different patient IDs actually indicate the same person. For this purpose, when a certain local EHR system issues a patient ID, an authorized organization can issue an upper-level patient ID for the national level, and can manage the links between patient IDs in multiple local EHR systems [18]. Using this mechanism, when a search for user data is performed using any local EHR system patient ID, it is possible to send a search request to other local EHR systems by means of the upper-level patient ID and return complete and integrated search results. Figure 2 shows a concept diagram of this process.

Actual system

In this study, we constructed a nationwide-capable EHR directory service (super site), with named "Super Dolphin" that includes the XML data mapping and upper-level directory structure described earlier, and verified that it is possible to link multiple local EHR systems together. Specifically, the subjects were two regions of Japan (Miyazaki and Kyoto) where EHR systems are actually operating. These two local EHR systems were connected to the super site that we constructed, and this super site was given the name "Super Dolphin". The NPO Japan Medical Network Association, which was established since 2005 to implement nationwide EHR manages this super site [19].

Table 1 is an overview of the two local EHR systems which were the subjects of this test.

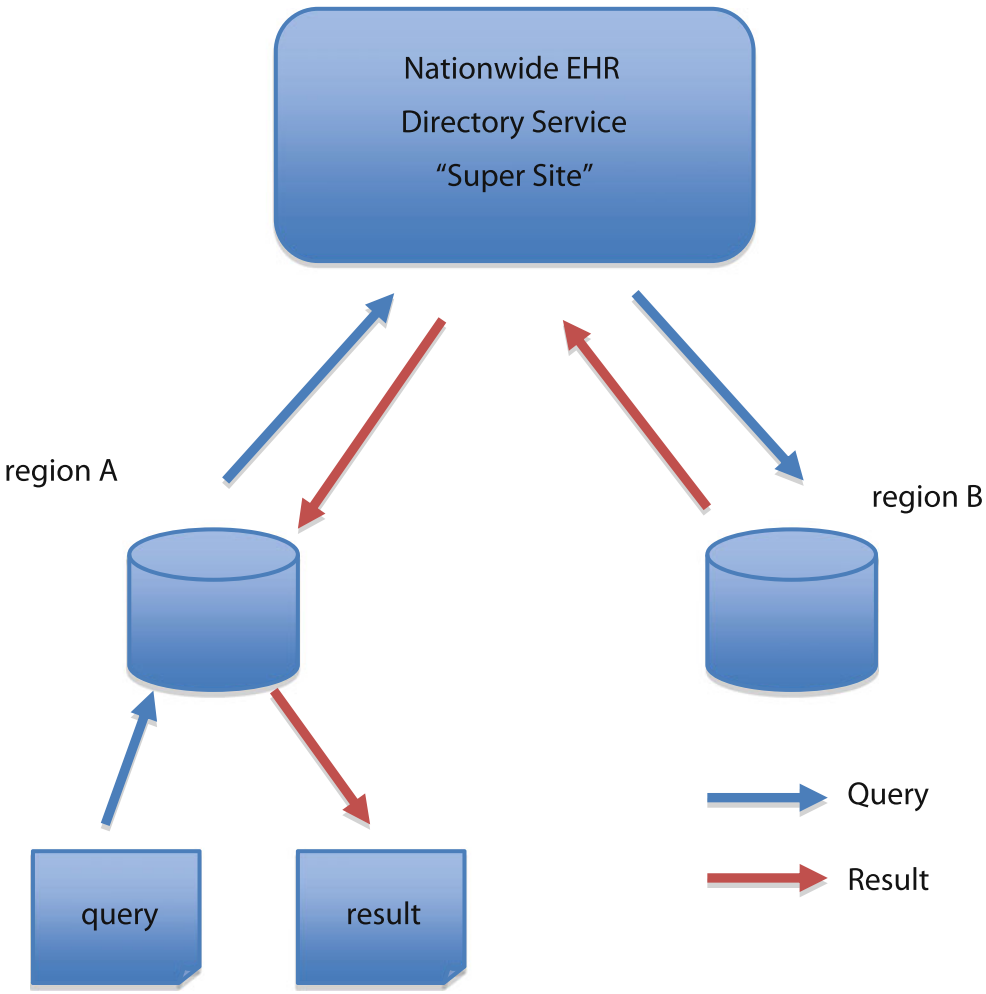


Fig. 2 Concept diagram of upper-level directory structure

Table 1 Test conditions

1) Local EHR systems and using data formats
Miyazaki EHR system (haniwa): Using MML2.3
Kyoto EHR system (maiko): Using MML3.0 (CDA* rel.1 compliant)
2) Upper-level site: Super Dolphin
3) Paths: The two local EHR systems and Super Dolphin were connected by Japan Gigabit Network version2 (JGN2**)
The internet is used for the communications route from the medical institutions to the center server

*CDA** clinical document architecture

JGN2** is research and development testbed network operated by the National Institute of Information and Communications Technology (NiCT) in Japan

Both the Miyazaki and Kyoto EHR systems are EHR systems that were constructed within the framework of the Dolphin Project [2]. The Dolphin Project was proposed by Yoshihara et al. in 1997 [11], and took its first step toward becoming reality in 2000 as a R&D project of the Ministry of Economy, Trade and Industry, Japan. Subsequently, experimental EHR services were launched in two regions, Kumamoto [20] and Miyazaki [21], in December 2001 and remain in use today. Later, full-scale projects aimed at providing practical services were launched in Tokyo [22], Kyoto [23], and other major cities.

The framework of the Dolphin Project involves integrated management of the medical data stored in the EHR system central server under a certain level of security. This allows medical practitioners to centrally view the medical data of patients who have concluded treatment agreements, and allows coordinated medical care. Patients can also view their own medical data (electronic record disclosure) and can enter symptoms and other information into their own records. The central server is connected to clinics, hospitals, laboratory test services, pharmacies, home nursing-care stations, and other facilities, which can send information such as past histories, laboratory results, letters of introduction, and discharge summaries. This information is all integrated and stored for each patient. In addition to sharing of local treatment data, this information is also used as a backup for the record data of each medical institution. In the Dolphin Project, the data of each medical institution is sent to the central server using MML, HL7, or other data format and is stored by the server in a database. A web interface is provided to the patients and medical practitioners. At present, each region is currently operating an original system utilizing the above basic design but making use of the local characteristics. The scale of each local project is as shown below (Table 2).

In this study, each patient is issued a unique patient ID in the local EHR system where person wants to receive service. Using this ID, the patient is able to view pateient's own medical information within the region. When a patient wants to view his/her own medical information from another region, by linking the patient IDs from multiple local EHR systems, Super Dolphin allows medical information from different regions to be viewed.

When a search for medical information is performed on the Miyazaki or Kyoto system, first a query is sent to the database of that local EHR system using the patient ID as the key. At the same time, the local EHR system sendsa query to Super Dolphin to check whether or not that patient ID is linked with patient IDs in other regions. As a result of this query, if the patient ID is found to be linked to an EHR system patient ID in another system, Super Dolphin uses this link information to request a search. The obtained data is converted to the data structure used by the data center which sent the request, and displayed. Communications between each EHR system and the super site utilize a local area network that uses the JGN2 network (Japan Giga Network version2) [24] provided jointly by the Ministry of Internal Affairs and Communications (MIC) and by NiCT. For local EHR systems and users, communication uses SSL with security functions utilizing Certification Authorities. The overall configuration is shown in Fig. 3.

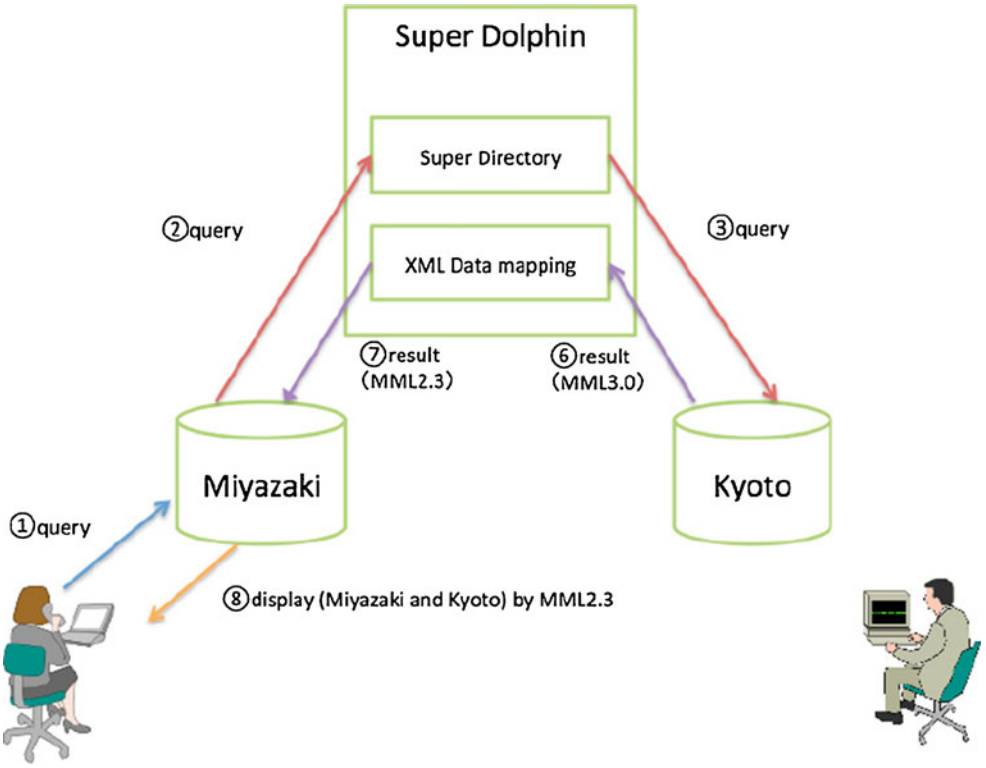
Results

Figure 4 shows an example of the results from display of patient medical data.

Table 2 The scale of each local project

	Miyazaki	Kyoto
Registered patients	1078	1,100
Registered medical institutions	84	5
Registered physicians	478	2,000
Monthly views (physicians)	185	100
Monthly views (patients)	60	2,000
No. of documents sent (text)	1,600,000	7,000,000
No. of documents sent (images)	85,000	86,000
Year started	2002	2007

Measurement date is 30 Oct 2010



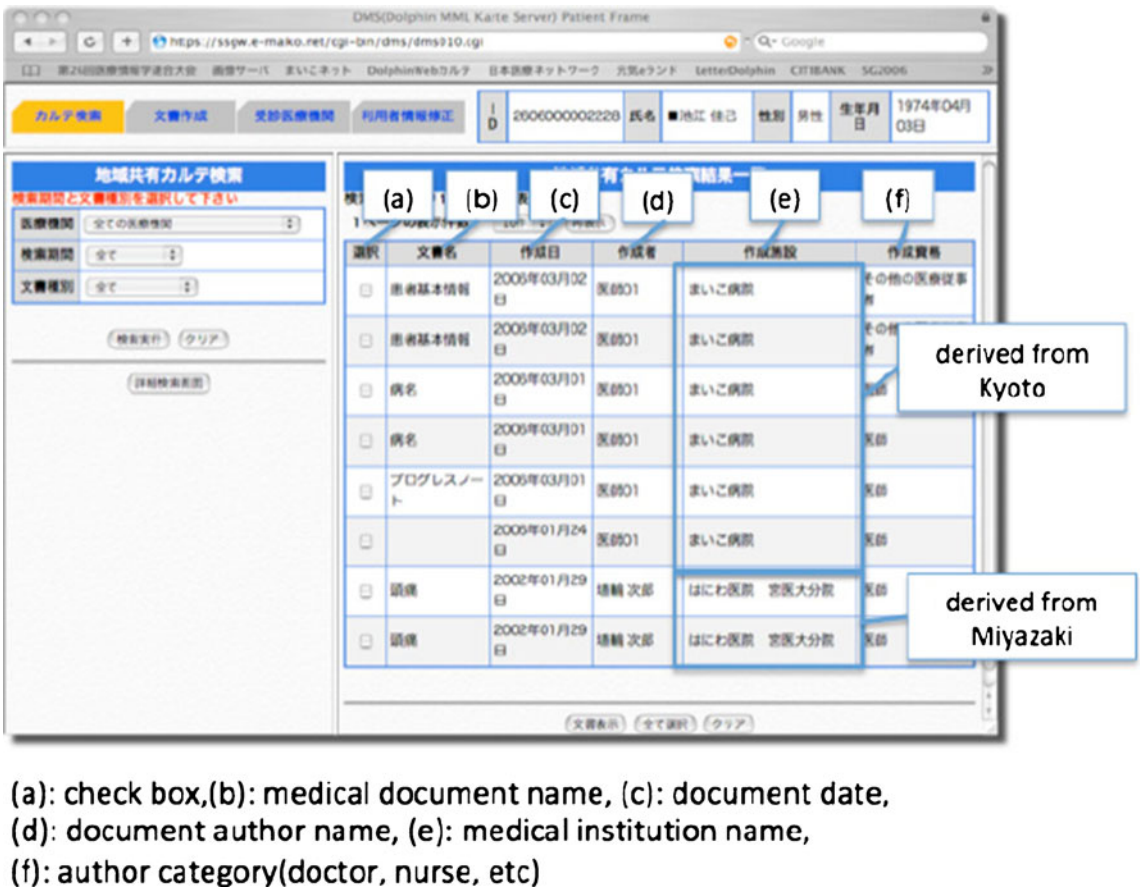


Fig. 3 Overall super dolphin configuration

Fig. 4 Patient medical data

The medical data is organized into lists that are based on the MML structure and that include disease name information, laboratory information, and progress reports. The fifth column in the list indicates the medical institution where the patient was treated. "Maiko Hospital" in this column indicates a Kyoto area medical institution and data which was uploaded to the Kyoto EHR system in CDA rel.1 (MML3.0) format. On the other hand the data of "Haniwa hospital" was uploaded to Miyazaki EHR system in MML2.3 format. In this way, this super site is able to merge and display data from EHR systems in different regions.

Observations

In this study, we considered, and verified by testing, a mechanism for integrating local EHR systems and providing medical cooperation that spans multiple regions. We constructed a super site (Super Dolphin) with data mapping functions for the purposes of matching patient IDs from different regions using an upper-level directory structure, and of compatibility between different data structures. Japan Medical Network Association was established as the operating body for operation of this super site. Although the upper-level directory structure is simple, it is highly universal and is expected to provide large benefits for medical cooperation between regions within a country and with regions where a unique national-level ID cannot be used. In this study, we also succeeded in mapping between different data structures. As described before, in this case conversions were only performed in one-to-one combinations (MML2.3 and CDA rel.1(MML3.0)). Naturally in order to use this mechanism to handle a broad range of clinical data in a versatile manner, the development of a correspondence table for the various standards will be necessary. In this case, determining how to coordinate the different levels of detail in the information may be a larger problem than mapping. However, the structures of the minimum necessary data that needs to be recorded for medical purposes do not differ greatly, and we believe that there will be no serious problems. In the future, we intend to increase the number of local EHR systems which participate in this super site and verify the effectiveness of this fundamental infrastructure, working towards achieving a national-level EHR.

References

1. Canada Health Infoway https://www.infoway-inforoute.ca/about-infoway/news/open-letter-to-canadians/canadas-ehr-progress, last accessed Jan 16 2011
2. NHS online http://www.nhsonline.org/attachments/NHS_Reprint_P1.pdf, last accessed Feb 16 2011
3. Examples of EHR in Japan (Japanese) http://www.wam.go.jp/wamappl/bb13GS40.nsf/0/976ec0d3117a45cf4925708a001e8e62/$FILE/siryou2-1.pdf, last accessed Feb 16 2011
4. The number of Americans who moved declined sharply last year http://www.cleveland.com/business/index.ssf/2009/04/the_number_of_americans_who_mo.html, last accessed Nov 2 2010
5. Statistics Bureau and the Director-General for Policy Planning and Statistical Research and Training Institute, Ministry of Internal Affairs and Communications of Japan. http://www.stat.go.jp/english/index.htm, last accessed Feb 16 2011
6. Takada, A., Guo, J., Tanaka, K., Sato, J., Suzuki, M., Suenaga, T., Kikuchi, K., Araki, K., and Yoshihara, H., Dolphin project—Cooperative regional clinical system centered on clinical information center. *J. Med. Syst.* 29(4):391–400, 2005.
7. Halamka, J. D., Making the most of federal health information technology regulations. *Health Aff.* 29(4):596–600, 2010.
8. Halamka, et al., Health care IT collaboration in Massachusetts: The experience of creating regional connectivity. *J. Am. Med. Inform. Assoc.* 12(6):596–601, 2005.
9. 2009 MIC communication use trend survey. http://www.soumu.go.jp/main_content/000064217.pdf, last accessed Feb 20 2011
10. Eichelberg, M., et al., A survey and analysis of electronic healthcare record standards. *ACM Comput. Surv.* 37(4):277–315, 2005.
11. Araki, K., Ohashi, K., Yamazaki, S., Hirose, Y., Yamashita, Y., Yamamoto, R., Minagawa, K., Sakamoto, N., and Yoshihara, H., Medical markup language (MML) for XML-based hospital information interchange. *J. Med. Syst.* 24(3):195–211, 2000.
12. Guo, J., Takada, A., Tanaka, K., Sato, J., Suzuki, M., Suzuki, T., Nakashima, Y., Araki, K., and Yoshihara, H., The development of MML (Medical Markup Language) version 3.0 as a medical document exchange format for HL7 messages. *J. Med. Syst.* 28(6):523–533, 2004.
13. Health Level 7 (HL7). http://www.hl7.org/, last accessed Nov 2 2010
14. Yoshihara, H., Applications of electronic medical records to local cooperative health care—Cooperative health care on the national level in Japan by linking EHR systems. *J. Jpn. Med. Assoc.* 135(9):1989–1992, 2006.
15. Maldonado, J. A., et al., LinkEHR-Ed: A multi-reference model archetype editor based on formal semantics. *Int. J. Med. Inform.* 78(8):559–570, 2009.
16. ASTERIA. http://www.infoteria.com/en/, last accessed Nov 2 2010
17. Rhapsody. http://www.orionhealth.com/products/rhapsody/, last accessed Aug 12 2010
18. Yoshihara, H., Minagawa, K., and Tanaka, H., The concept of Global Medical History Database (GMHD) and Its prototype. *Jpn. J. Med. Inf.* 17(3):237–240, 1997.
19. NPO Japan Medical Network Association http://www.ehr.or.jp/, last accessed Feb 20 2011
20. Higo-Med Project. http://133.95.89.5/dolphin/, last accessed Feb 20 2011
21. Haniwa net. http://www.haniwa-net.jp/, last accessed Feb 20 2011
22. HOT project. http://www.ocean.shinagawa.tokyo.jp/hot/, last accessed Feb 20 2011
23. Maiko-Net. http://www.e-maiko.net/, last accessed Nov 2 2010
24. Japan Gigabit Network. http://www.jgn.nict.go.jp/english/index.html, last accessed Nov 2 2010