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History of PACS in Asia

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ABSTRACT

First, history of PACS (picture archiving and communication system for medical use) in Japan is described in two parts: in part 1, the early stage of PACS development from 1984 to 2002, and in part 2 the matured stage from 2002 to 2010. PACS in Japan has been developed and installed by local manufacturers by their own technology and demand from domestic hospitals. Part 1 mainly focuses on quantitative growth and part 2 on qualitative change. In part 2, integration of PACS into RIS (radiology information system), HIS (hospital information system), EPR (electronic patient record), teleradiology and IHE (integrating healthcare enterprise) is reported. Interaction with other elements of technology such as moving picture network system and three dimensional display is also discussed. Present situation of main 4 large size hospitals is presented. Second, history of PACS in Korea is reported. Very acute climbing up of filmless PACS diffusion was observed from 1997 to 2000. The reasons for such evolution are described and discussed. Also changes of PACS installation and system integration with other systems such as HIS and role of them in radiological diagnoses in Korea since 2002 are described. Third, history in China is investigated by checking international academic journals in English and described as far as events are logically linked and consistently meaningful.

1. Introduction

A paper on PACS development in Asia was once published in 2003 [1]. However, the history of development and operation of PACS in Asia involving China has not been reported since then. Also no clinical evaluation of installed PACS in Asia has been performed. Consequently, we should know whether PACS is used because it is found to be cost-effective or merely because PACS is expected to be so. This question has to be discussed. Therefore the chronological evolution, development and clinical use of PACS should be traced for these 26 years right form 1984, and presented.

2. History of PACS in Japan

2.1. Materials and methods

Most statistical raw data were acquired by survey results carried out by a Japanese journal "Gekkan Shin-iryou" ("Monthly Bulletin of New Medicine") published by "ME Shinkou Kyoukai" (medical engineering promoting association) and Japan Industries Association of Radiological Systems. Back numbers of this Japanese journal published in Japanese were referred to, and necessary data were picked up, collected, compiled, edited, and presented graphically or in the form of timeline tables.

In part 1:

(1) Quantitative growth of PACS, such as the number of installations and size of systems was chronologically traced from year 1984 to 2002. These comprise small PACS units with less than four image display terminals (IDTs), medium-size PACS with >5 and <14 IDTs, and large-size PACS with >15 up to 1300 IDTs [1].
(2) The configuration of the large-size PACS was retrospectively figured out since 1984.
(3) Events in progress of PACS development in Japan from 1984 to 2002 were investigated. A baseline study was carried out in Osaka University Hospital to assess the PACS contribution to image diagnosis with HIS. The response time of image retrieval from PACS terminals was measured [2].
(4) Standardization activity in Japan which contributed to PACS development was looked into and described.

In part 2, qualitative change in PACS utilization was evaluated during 2002 and 2010.

(1) Qualitative factors which influenced PACS operation were picked up. These factors were integrated with RIS, HIS and EPR.

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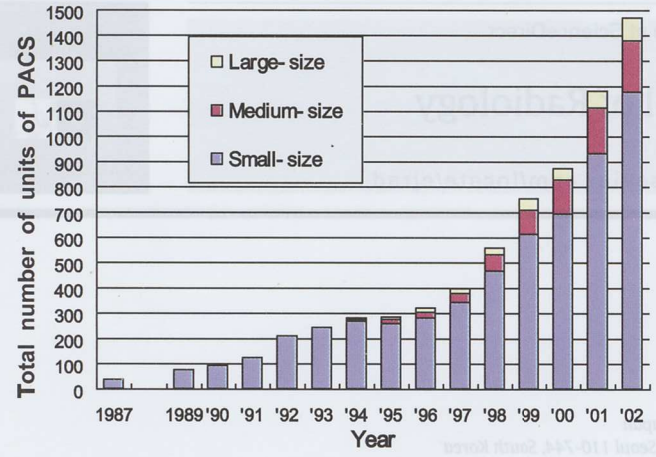

Fig. 1. Progress of PACS diffusion in Japan during years 1987–2002. Even small-size PACS of 1173 units in 2002 had function for image collection, storage, image processing, display, hard copy and image transmission through network. A rapid build-up of PACS installation was observed especially from 1997 to 2002. Continuous growing up of PACS diffusion from 2001 to 2010 in Japan is shown in Fig. 3.

(2) Interaction with other elements of PACS operation such as moving picture network system and 3D (three-dimensional) display was also searched.

2.2. Result

Part 1:

Fig. 1 shows the chronological change of PACS diffusion from 1987 to 2002 in Japan [3].

Even small-size PACS of 1173 in 2002 had function for image collection, storage, image processing, display, hard copy and image transmission through network.

Table 1 describes the present situation of large size PACS operation in Japan. Main 4 PACS are picked up [3].

The first experimental PACS and the first practical PACS were installed in Osaka University in 1984 [2] and in Hokkaido University Hospital in 1989, respectively. Note that most hospitals in Table 1 have several PACS servers. These servers were purchased from different vendors. The number of hospitals which had beds above 20 in 2002 was about 9000 in Japan. So that about 12.5% of hospitals had PACS in 2002.

Table 2 shows main progress from 1984 to 2002.

Japan began its own standardization activity such as MIPS (Medical Image Processing Standard) and ISAC (Image Save and Carry) in 1984 and this influenced PACS development in Japan. But soon in1990 these domestic standards were replaced by Japanese version of DICOM. Fig. 2 describes the history of standardization activity in Japan and even in Korea.

Concept of IHE (integrating healthcare enterprise) is now prevailing in Japan as IHE-J, and is contributing to PACS operation together with HIS and RIS.

Part 2:

Fig. 3 shows chronological change of number of hospitals equipped with PACS comparing with that utilize HIS, EPR and RIS [4].

Data between 2002 and 2006 in Fig. 3 were missing because the surveys were not carried out at that time. Fig. 4 shows chronological change of the number of hospitals which employ moving picture network systems and three dimensional display systems [4]. Fig. 1 shows the number of PACS systems while Figs. 3 and 4 shows the number of hospitals of PACS operation.

Table 1
Present situation of large size PACS operation in Japan.

No.	Hospital	Number of PACS servers	Number of connected modalities	Number of terminals	Integration with HIS, RIS and electronic patient record	Integration with teleradiology	Number of terminal for moving picture network systems	Number of terminal for three dimensional display systems	Since	Notes
1	Hokkai-do University	8	25	More than 1500	○	○	21	17	1988	First PACS Operation in Japan
2	Osaka University	6	28	More than 1500	○	○	4	22	1984	First PACS Experiment in Japan
3	Kyoto University	6	23	1400	○	○	20	22	1989	
4	Nagoya University	1	15	1250	○	○	14	11	1989	Tele-radiology coupling

Connected modalities mean on-line connected diagnostic machines such as CT, MRI, digital radiography, and ultra-sound. Recent growing up of flat panel detector radiography is the main tendency of image collection to PACS servers. Most of university hospitals are now equipped with teleradiology systems which enable us image retrieval and display from outside satellite hospitals as if they are inside images.

Table 2
History of PACS in Japan during years 1984–2002.

Year	Events
Small size and medium size PACS	
1984	MedFile series (NEC), NEPACS Enterprise (NEC)
1988	TDS-File (Toshiba)
1984	Film digitizer by CCD (NEC)
1986	Image compression hardware (NEC)
Large size PACS	
1984	Experimental PACS in Osaka University (NEC)
1989	Clinical PACS in Hokkaido University (NEC)
1989	Experimental PACS in Kyoto University and Nagoya University
Teleradiology	
1984	Experiment in Nagasaki Pref. (NEC)
1987	Experiment by satellite communication in Harumi (Toshiba)
1989	Commercial teleradiology (SECOM)
Standardization activities	
1984	Standardization by JIRA following ACR-NEMA
1984	IS&C (Image Save and Carry) started
1985	DICOM in Japanese version
2002	IHE-J demonstration (JIRA, JRS, JSRT, JAHIS)

Only 2 years and 4 years later from 1982 when first terminology of PACS appeared in Newport Beach in USA, dedicated hardware for film digitizing and image data compression were commercialized by a domestic manufacturer in 1984 and 1986 in Japan, respectively. More than 6 domestic manufacturers produced small size PACS in Japan since 1984, but some of them disappeared and were replaced by foreign manufacturers. History of standardization activities is also shown in Fig. 2.

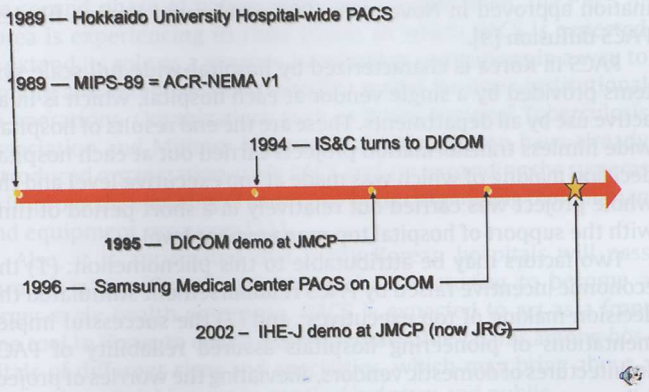

Fig. 2. Standardization activity at early stage in Japan until 2002. Note that ACR-NEMA version 1 was translated into Japanese in 1989 immediately after it was published in USA. ISAC means "image save and carry" describing the standard for off-line image transmission peculiar to Japanese clinical environment. IHE-J is the Japan organization of integrating healthcare enterprise.

2.3. Discussion

A rapid build-up of PACS installations can be observed in part 1, 1984–2002. However, about 80% of systems are small-size PACS.

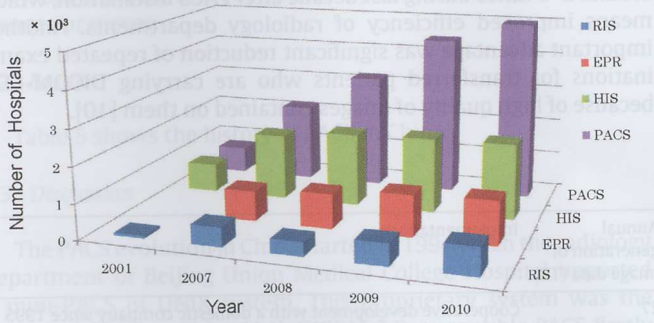

Fig. 3. The number of hospitals equipped with PACS, EPR, RIS and HIS. Continuous increase of the number of PACS equipped hospitals is observed from 1984 to 2010 as shown in both Fig. 1 and this figure. The number of hospitals which operate HIS, RIS and EPR are rather small or saturated compared with that of PACS.

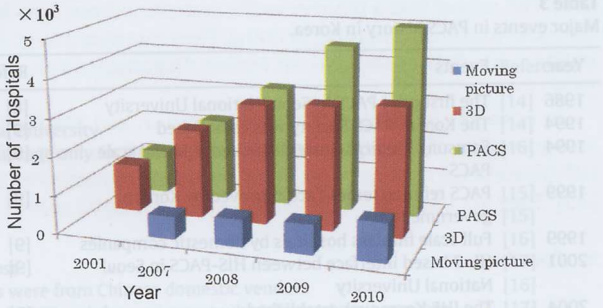

Fig. 4. The number of hospitals which are equipped with PACS, 3D display systems and moving picture network. 3D display systems have the function of three-dimensional display most of which are for CT, MRI, ultra-sound and treatment planning. Moving picture systems are for ultra-sound, angiography and dynamic digital radiography of cardiac use.

The number of hospitals with more than 100 beds in 2002 was 5448 in Japan. So, the total number of PACS installation 1468 in 2002 meant that about 27% of hospitals of more than 100 beds had PACS in Japan.

On the other hand, in part 2, the total number of hospitals which have PACS operation in April 2010 is 4996 and the number of hospitals with beds more than 20 is now about 8600 in Japan. So, about 58% of hospitals have PACS operation. The number of hospitals and clinics of below 19 beds which have HIS operation in April 2010 is 2112. So we can say PACS diffusion in Japan is more than that of HIS.

Remarkable phenomenon is that only 15% of PACS equipped hospitals have RIS. This is unconceivable situation compared with that in USA or Europe. The reason is that radiological reports are not evaluated by health insurance system very much, and on the other hand the number of medical images taken for a patient is the target of numeration. Besides, attending physicians in other departments than radiology departments do not rely on radiological report issued by radiologists, and they diagnose by interpreting medical images directly sent from radiology department.

As Fig. 4 shows, ratio of PACS installation with 3D display function compared with that of total number of PACS operation is very high. This is the result of large number of diffusion of multi-detector CT and MRI in Japan. The number of working MRI is 6153 as of April 2010, so that we can say 81% of MRI is supported by 3D PACS nowadays in Japan.

As shown in Tables 1 and 2, PACS integration into HIS started from very early stage of clinical PACS operation. These tables support the fact that PACS has been operated for "Primary Diagnosis".

Table 2 indicates that PACS in Japan started in 1984 which was 2 years later of that in USA when terminology of PACS originated in 1982 in Newport Beach. The progress of PACS diffusion had been rather with high speed.

In Osaka University PACS with 20 image display terminals was clinically coupled with HIS/RIS firstly in Japan in 1996. In order to maximise the benefit of PACS and to measure the contribution of PACS quantitatively, we studied the effect of the HIS/RIS coupling with PACS [5,6]. The result indicates that HIS coupled with PACS contributes to image diagnosis very much beyond our expectation [7]. PACS in Osaka University Hospital was updated in 2002, 2005, 2008 and 2010.

Configuration and operation of PACS have been completely changed in these 24 years. Four university hospitals picked up in Table 1 had these changes. Every university hospital has teleradiology operation together with their satellite hospitals. Images from satellite hospital can be retrieved without any special manipulation of "teleradiology". It should be noted that meaning of PACS in 2010 is different from that in 2002.

Table 3
Major events in PACS history in Korea.

Year	Events	Reference
1986	The first pilot PACS in Seoul National University	[8]
1994	The Korean PACS Society was established	[9]
1994	Samsung Medical Center launched a partial scale PACS	[9]
1999	PACS reimbursement act approved by Korean government	[9]
1999	Full scale filmless hospitals by domestic companies	[9]
2001	HL-7 based interface between HIS-PACS in Seoul National University	[9]
2004	The IHE Korea was established	[8]

Only 4 years later from 1982 when the first word of PACS appeared in USA, the first PACS in Korea was tried in Seoul National University in 1986.

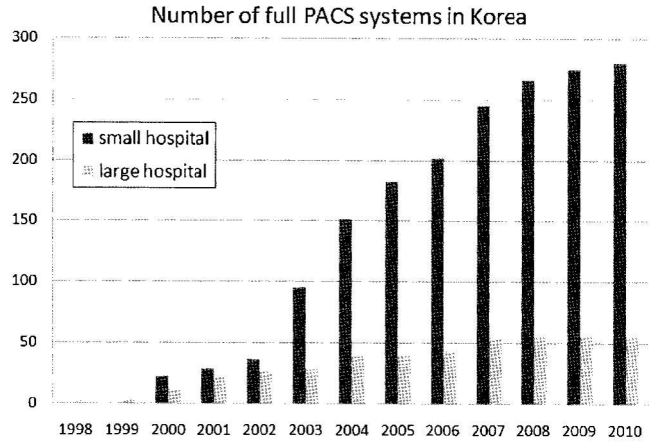

Fig. 5. The number of full PACS systems installed in Korea. Sudden increase of the number of small hospitals which are equipped with full PACS since 2002 is observed. The reason is discussed in the text.

3. History of PACS in Korea

3.1. Materials and methods

Development of PACS and related systems in Korea was studied retrospectively by key persons who had been taking part of it and reconfirmed by literature. Fortunately Korean Society of PACS and Korean Society of Imaging Informatics in Medicine had official records of it. So, we could trace (1) main events in PACS development in Korea from 1982 to 2009, (2) the number of PACS installations in Korea from 1986 to 2010 and (3) the status of the large-size PACS installations.

3.2. Result

Table 3 depicts major events in PACS history in Korea [8–13]. Fig. 5 shows the number of PACS systems installed in filmless hospitals from 1998 to 2010 [9,13].

According to the contributions from KSIIM (Korean Society of Imaging and Information in Medicine), there are more than 7 domestic manufacturers in Korea. A number of them had started with hospital information system. Three examples of large-scale PACS systems installed by both domestic and foreign companies are listed in Table 4.

It is noticeable that PACS development projects were initiated in several university hospitals including Seoul National University Hospital and Asan Medical Center to implement their own PACS using different system architectures in cooperation with domestic companies after successful PACS installations at Samsung Medical Center for the first time in 1994. Among them, the architecture developed by Seoul National University Hospital was most successfully accepted as cost-effective and reliable one, and had spread over many hospitals in Korea.

3.3. Discussion

One major impetus in propelling Korean PACS development was the national policy of reimbursement for PACS examinations approved in November 1999. Both National Health Insurance Corporation (NHIC)'s and Health Insurance Review Agency (HIRA)'s PACS Reimbursement Act contributed to the success of the PACS development in South Korea. It should be also pointed out that Korea does not have domestic industry of X-ray film manufacturing, and the economic crisis in 1997 prevented import of X-ray films. And then, national policy of reimbursement for PACS examination approved in November 1999 accelerated Korean filmless PACS diffusion [9].

PACS in Korea is characterized by hospital-wide full scale systems provided by a single vendor at each hospital, which is in an active use by all departments. These are the end results of hospital-wide filmless transformation projects carried out at each hospital, decision making of which was made at top executive level and the whole project was carried out relatively in a short period of time with the support of hospital top management level.

Two factors may be attributable to this phenomenon: (1) the economic incentive raised by PACS reimbursement stimulated the decision making of top executives; and (2) the successful implementations of pioneering hospitals assured reliability of PACS architectures of domestic vendors, alleviating the worries of project failure.

An important feature in Korean PACS systems is good harmonization with international standards such as DICOM and IHE. The Korean PACS society pursued a nation-wide implementation of open system to international standards from its beginning, believing that adoption of international standards would be a key to the rapid development of national level of PACS realization into the next dimension.

The nation-wide dissemination of PACS in Korea provided important benefits at least in several aspects. Most of hospitals experienced growth in the number of imaging examinations around 2–3 times during last decade after PACS installation, which means improved efficiency of radiology departments. Another important advantage was significant reduction of repeated examinations for transferred patients who are carrying DICOM-CDs because of high quality of images contained on them [10].

Table 4
Profiles of representative large scale PACS in Korea.

No.	Hospital	Number of beds	Number of connected modalities	Number of terminals	Annual generation of image data (TB)	Implementation
1	Seoul National University Hospital	1500	250	3000	27	Cooperative development with a domestic company since 1995
2	Samsung Medical Center	1200	190	3000	25	Purchase from a foreign company in 1994
3	Asan Medical Center	2200	250	3500	24	Cooperative development with a domestic company since 1995

Large number of connected modalities and display terminals reflects their complete filmless PACS operation covering all imaging modalities across the hospital.

Table 5
History of PACS in China.

Year	Events	Reference
1994	The first mini-PACS in Beijing Union Medical College Hospital	[14]
1996	The first DICOM 3.0 compatible PACS in affiliated hospital of West China. Medical University	[14]
1997–1998	PACS was growing slowly because of only UNIX workstation, DICOM software package only for UNIX, the less of DICOM imaging modalities and Asia Financial Crises	[16]
1998	The academic community summarized the experience in the practice of PACS	[15]
1999	The Ministry of Health in China approved integrated and applicable PACS	[15]
1999–2001	Eleven hospitals imported MiniPACS from abroad	[16]
2000	Shangai Jiao Tong University developed their own image archive sever of low cost	[17]
2001–2002	Eight hospitals purchased whole hospital PACS systems. Among them 4 systems were from Chinese domestic vendors	[16]
2003	Affiliated Hospital, Guiyang Medical College reported construction and cabling of PACS and the equipment which formed the necessary platform to run PACS and HIS. There were more than 50 terminals. All components were from manufacturers outside China	[17]
	A boom of PACS adoption by SARS crisis	[14]
	National projects started to develop health IT standards unique to China	[18]
2004	Healthcare professionals established a relationship with the U.S. IHE organization, with a view to launching IHE-China	[18]
2005	A draft of DICOM 3.0 compliant PACS with Chinese characteristics	[14]
2007	Shenyang city Hospital of 2300 beds replaced their CRT monitors by LCD technology	[20]
	The first Connectathon by IHE-China. Five vendors participated	[19]
2008	The functionality of IHE workflow profiles in RIS/PACS installations	[21]
2009	The Sun Yat-sen University in Guangzhou, decided to convert completely to digital radiology	[22]
2010	Hong Kong Sanatorium and Hospital linked an agreement of PACS monitoring, database-driven reporting and HIPAA/audit log management.	[23]

In spite of slow start of PACS installation in Chinese hospitals, very acute build-up to catch up with global level is observed.

After the first phase of exploring technical architectures and the second phase of nation-wide rapid proliferation, the PACS in Korea is experiencing its third phase, in which PACS is expected to extend its role as a synapse interlinking institutions in a way to explore and establish a best possible model for inter-institutional co-operations. Organizations such as Korea National Tuberculosis Association and Military Manpower Administration have already introduced organization-wide PACS and are expanding the systems to improve their quality of service by better organizing their human and equipment resources [11].

Also, it is anticipated that many Korean hospitals will pass through a significant organizational restructuring to become a larger-scale health enterprise. PACS is expected to act as a front line tool in Korea to create experimental value-chains among hospitals of different sizes and specialties, which may bring about a deeper beneficial impact to medical industry and public.

4. History in China

4.1. Materials and methods

There is no literature of statistical raw data in China as Japan and Korea have. So, international academic journals were checked out by the author. Information was extracted from internet references through query using different combinations of keywords. Some fragmented information was found; so it was difficult to acquire a story. But we could find out fact data by cross checking from double sources or pieces.

4.2. Result

Table 5 shows the history of PACS in China.

4.3. Discussion

The PACS evolution in China started in 1994 when the radiology department of Beijing Union Medical College Hospital imported a mini-PACS of UNIX system. This proprietary system was the first mini-PACS in China [14]. DICOM 3.0 compatible PACS firstly appeared in China in 1996 when a Siemens PACS was installed by the first affiliated hospital of West China Medical University [14]. The main work from 1995 to 1998 was to introduce PACS [14,15].

In 1997–1998, PACS was growing slowly in China because of only UNIX workstation, DICOM software package only for UNIX, the less of DICOM imaging modality and Asia Financial Crises [16].

From the year 1999–2001, there was an era of mini-PACS solution. Eleven hospitals imported MiniPACS [16]. From the year 2001–2002, whole hospital PACS solution prevailed in China. Eight hospitals purchased such systems. Among them 4 systems were from Chinese domestic vendors [16].

A study was performed to evaluate the situation, problem, and healthcare integrating encountered in the implementation of a PACS in various clinical settings in the radiology department and hospital in China. Integrating with HL-7 and IHE was introduced [16].

Since the latter half of 1998, the academic community had summarized the experience in the practice of PACS [15]. The local PACS developers in China had to face hot market competition with international rivals, especially after the entrance of China to WTO. It is very disadvantageous for vulnerable PACS developers of China [15].

In 2003 affiliated hospital in Guiyang Medical College, reported construction and cabling of PACS and the equipment which formed the necessary platform to run PACS and all kinds of HIS together. There were more than 50 terminals. All component manufacturers were again from outside China. Through 1 year of operation, the PACS in their hospital had a failure rate of 5% to 1%, far below 7%, the average failure rate of normal medical equipment in China [17].

Healthcare professionals in China established a relationship with USA IHE organization in 2004, with a view to launching IHE-China [18]. In 2007 the first Connectathon was hosted by IHE-China in Shanghai. Five vendors participated [19].

In 2007 Shengjing hospitals of 2300 beds replaced their CRT monitors by LCD technology [20].

In 2008 Zhe Xu et al. reported the functionality of IHE workflow profiles in RIS/PACS installations [21]. The scheduled workflow and reporting workflow were already contributing positively to the daily running of radiology departments, according to their analysis [21]. Implementing PACS with an IHE approach revolutionized their daily work. IHE promoted a number of powerful features [18]. These include structured reporting, presentation state, key image notes, encapsulated document, waveform, spatial registration, and removal media storage [18].

In 2009 The Sun Yat-sen University Cancer center in Guangzhou, South-China, decided to convert completely to digital radiology

[22]. The center was a pioneer in the transition from film-based to film-less diagnostic imaging in China. They installed a large number of Barco Nio Fusion and Coronis Fusion diagnostic display systems [22].

In June 28, 2010, Hong Kong Sanatorium and Hospital linked an agreement of PACS monitoring, database-driven reporting and HIPAA/audit log management with a company by name PACSHealth [23]. They are expected to be alive by October 2010 at the facility.

5. Conclusion

History of PACS in Japan, Korea and China is reviewed. First PACS in each country was born in 1984, 1986 and 1992 in Japan, Korea and China, respectively, while the first PACS terminology originated in USA in 1982.

Progress of PACS development depended deeply on social situation in each country such as health insurance system, structure of industries, economic crises and political decision-making, as well as technical exploration by domestic industries.

PACS has clearly proved its values in different countries of Asia in terms of cost effectiveness and contributions to medical economy, even though it suffered from financial burdens and technical difficulties in integrating into informatin systems and standards at initial stages of introduction.

PACS development has been closely related to and synchronized with that of RIS (radiology information system), HIS (hospital information system), EPR (electronic patient record) and even teleradiology. Nowadays PACS is operated with the concept of IHE (integrating healthcare enterprise) in each country.

Influence of international standard DICOM was so strong that latecomer of PACS prevalence as China could easily catch up with early riser as Japan. Japan once had its own standardization activity, but resumed to DICOM later.

We learned that PACS is evolving together with the development of technologies such as flat panel detectors and flat panel displays, along with the strong demands from diagnostic modalities such as multi-detector CT, MRI and ultrasound which ask for additional capabilities including three dimensional display and moving picture display.

Future deployment of PACS would be influenced by newly coming technologies such as mobile terminals and CAD (computer aided diagnosis).

Conflict of interest

The authors do not have any conflicts of interests.

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