Assessment of Methods Used to Import External Brought-in Image Data Using Activity-Based Costing/Activity-Based Management

Minoru Kawamata[1,3,*], Yasuhiko Yamane[1], Takashi Horinouchi[1], Katsuyuki Nakanishi[1] Kenichirou Shimai [2], Hiroki Moriguchi[3]

[1]Department of Diagnostic Radiology, Osaka Medical Center for Cancer and Cardiovascular Diseases

[2]Medical Information Center, Tokushima University Hospital, Japan

[3]Department of Medical Informatics, Institute of Biomedical Sciences,

Tokushima University Graduate School, Japan

*Corresponding Author:

Minoru Kawamata, MS

Department of Diagnostic Radiology, Osaka Medical Center for Cancer and Cardiovascular Diseases

1-3-3 Nakamichi, Higashinari, Osaka 5378511, Japan

Phone: +81-6-6972-1181, Fax: +81-6-6981-3239, E-mail: kawamata-mi@mc.pref.osaka.jp

ABSTRACT

Background: With filmless operation becoming widespread in Japanese hospitals, medical images provided for referral purposes are frequently stored using portable media such as compact discs. Few facilities import brought-in data into their own Picture Archiving and Communication Systems (PACS) with a clearly defined responsible creator at the time of data storage. Currently, no literature analyzing this series of tasks exists.

Objective: This study aimed to determine the best workflow for importing brought-in images into PACS in order to optimize management and costs.

Methods: We created three different importation operational workflows (post-medical examination importation, pre-medical examination importation, and pre-medical examination importation using Temporary PACS for storage), and clarified the decision maker, who decides when to lock and prevent further image modifications, and the responsible creator of the image. Task analysis of each operation was carried out using Activity-Based Costing and Activity-Based Management, methodologies used in the field of management accounting.

Results: Task analyses revealed that post-examination importation increased the burden on physicians, in addition to increasing operational costs. It was also shown that an explicit responsible creator did not exist with pre-examination importation. When pre-examination

importation was conducted using Temporary PACS, physicians were both decision makers and responsible creators. Moreover, the burden on physicians was low and the costs could also be kept low.

Conclusion: We analyzed importation tasks involved in bringing external images into PACS. Our results indicate that, from the perspective of management and costs, it is most efficient to import images using Temporary PACS servers.

Keywords: Activity-Based Costing (ABC), Activity-Based Management (ABM), Picture Archiving and Communication Systems (PACS)

BACKGROUND AND PURPOSE

Recent medical policies in Japan promoting digitalization in the field of healthcare have led most healthcare facilities to adopt filmless operations.[1-3)] Japanese citizens are obligated to participate in the public insurance system and are required to make payments for medical expenses according to the medical fees[4)]. The Central Social Insurance Medical Council evaluates medical practices and revises the medical fees every two years. These medical policies are greatly affected by medical fee revisions, and those for filmless operations is no exception. With the adoption of filmless operation, the method of image data sharing for regional hospital cooperation also changed. For patients with long medical histories, the form of image sharing shifted from heavy films to convenient portable media such as CDs with stored data. This shift reduced the burden on patients, who no longer need to carry heavy films, and also reduced the risk of losing medical records (image data), which the providing facility is obligated to maintain. Currently, transferring images stored on a CD, in compliance with the Portable Data for Imaging (PDI) standards,[5)] as defined by the Integrating the Healthcare Enterprise (IHE) initiative,[6)] is widely practiced.[7-9)] PDI images brought in from external facilities in this manner are usually stored in Picture Archiving and Communication Systems (PACS), with attribute information[10)] changed according to each facility.[11-12)] This

enables internal images and brought-in images to be viewed on the same device using electronic medical records or other software, thereby improving diagnosis efficiency. As a result, an increasing number of hospitals are storing all brought-in external PDI images in PACS in Japan[13-14] and other countries [7-9]. Reportedly, a data storage size of 1.4 TB is required for PDI images every year, using up a great volume of PACS capacity. [15] Such image transfers, however, may be conducted without clearly defining image information or the responsible creator, which we believe to be a crucial issue. Despite diagnosis efficiency being the top priority in clinical practice, the required precautions for electromagnetically storing images have not been sufficiently evaluated.

In March 2005, the Ministry of Health, Labour and Welfare released “Guidelines for safe management of medical information systems” (Safe management guidelines).[16] These guidelines include “Guidelines for storing medical records and related documents on electronic media in compliance with legal storing obligations” (including external storage of paper media) and “Information system operational management guidelines for personal information protection in medical- and nursing care-related facilities.” The Japanese Society of Radiological Technology focuses on the concept of “locked records” for confirmation of authenticity, as described in these “Safe management guidelines,” and requires clarification

of the “timing” of this process.[17)]

The process of initially storing image information in PACS includes a decision operator, with the individual conducting the operation being the responsible creator. When PDI images are stored in internal PACS, it is important to clarify both the timing of decision and responsible creator. Operation management standards should be established because it is unclear at what stage data can become the basis for a diagnosis. According to the “Law Governing the Use of Information and Communications Technology in the Preservation of Documents that Private Businesses Perform”[16)] (Ministry of Health, Labour and Welfare), the institutional requirements for responsibility in creation are described as follows: “Regarding electromagnetically recorded items, the responsibility pertaining to the creation of the subject electromagnetic records should be clarified.”

Business Process Management (BPM) is an approach used to manage task processes that is widely known for its efficiency.[18)] The Plan, Do, Check, and Act (PDCA) cycle proposed by Deaming[19)] can be cited as a typical example of BPM. While some reports in the literature have focused on BPM in the medical field,[20-21)] no previous studies have focused on the use of BPM in the field of radiation. The method used to store PDI images for PACS is very complicated as it involves many individuals. We aimed to clarify the problems that

occur after extracting the series of business processes to which BPM was applied in the present study.

The primary purpose of this study is to identify the cost structure of storing PDI images and determine the optimal workflow for importation operations using Activity-Based Costing and Activity-Based Management (ABC/ABM).

METHODS

Preparation of task process diagrams

The task of storing PDI images that are brought in from external medical facilities by referred patients in internal PACS requires great care. The task process by which PDI image data are stored in PACS after being received differs greatly depending on workflows, but can be divided into storing data before or after medical examinations. [13-14)] Workflow 1 was defined as the procedure of storing data in PACS after medical examinations, while Workflow 2 was defined as the procedure of storing data prior to medical examinations. Additionally, Workflow 3 was defined as the importation of data using Temporary PACS to store images prior to medical examinations. In the present context, Temporary PACS refers to a server that secures a specific domain on the hard disk in which old data is automatically deleted when the data volume exceeds the domain's capacity. [22)] Visualizing these three workflows allows

each task process diagram to be easily understood, while allowing for the identification of problematic issues.

The Unified Modeling Language (UML) method is used in this study to visualize task processes. The UML was approved as a modeling language standard by the Object Management Group (OMG) in 1997, and includes a specified form of Activity Diagrams.[23] These Activity Diagrams, which are commonly used to depict the control flow of programs and are useful for describing task orders,[24-25] were used to create task process diagrams. In each workflow, a circle indicates the initiation or completion of a task, while a rectangle indicates each task. The flow of each task is indicated by connecting them with arrows. Task process diagrams were created by interviewing medical assistants and radiation technologists who were involved in the daily tasks of image delivery. Task process diagrams were created using astah* professional 6.7.0 (Change Vision Co., Ltd., Japan).

Task analysis using ABC/ABM

Task analyses of the three workflows were carried out using the task process diagrams created as described above. In management accounting, direct costs are defined as items with identifiable prices, such as drugs. Conversely, indirect costs are those for which multiple

tasks are included, and determining the relationship between the source and the cost accounting subject is difficult. In examining referral patients, importation of brought-in external PDI images was included as an indirect cost because various occupations and departments were involved and it was not directly connected to the examinations. For task analyses, ABC, a method of accounting that addresses indirect cost allocation, was used. The ABC method calculates cost per activity unit by classifying tasks into smaller activity units.[26] By subdividing the task process into activity units, ABC enables the calculation of labor costs required for data importation.

While ABM uses ABC as an analysis tool for task improvement,[27] the main characteristic of ABC is that it separates final results into value-added activities (those that add value), and non-value-added activities (those that do not add value). The resulting information allows for re-examination of the overall task process by determining whether or not each activity is adding value to the product. Previous studies in the field of radiation[28-29] that used ABC showed most of the tasks related to storing brought-in external images in internal PACS to be non-value-added activities. Watanabe et al. demonstrated that the application of ABM improves systems with non-value-added activities.[27] The present study used ABM to evaluate activities within each task process, based on the cost accounting results obtained

from ABC.

In this study, each process was subdivided into activity units, according to the three task process diagrams. These activity units were then further separated into tasks carried out by physicians or tasks carried out by other staff members, and analyzed. In order to evaluate the task of storing PDI images in PACS, the cost drivers (criteria for assigning indirect costs in ABC analysis) of “time,” “unit price,” and “number of times” per activity unit were collected and analyzed. The mean time for each activity carried out behind the scenes, such as in outpatient examination rooms, was calculated. The unit price was based on the Basic Survey on Wage Structure announced by the Ministry of Health, Labour and Welfare in 2013.[30] Data on the number of times, value-added activities, and overall importation tasks were evaluated based on the average number of outpatients per month at our hospital. Therefore, we calculated the average PDI image size in our hospital’s PACS and Temporary PACS to estimate the cost of storage for a period of six months. The cost of storage was based on the cost required when our hospital expanded the capacity of PACS in 2012. Tukey’s HSD test was used for statistical analysis.

Based on these results and the analysis described above, we aimed to determine the optimal workflow for meeting guideline requirements. Data collection for the present study was

approved by the Institutional Review Board of our hospital.

RESULTS

The general operational task process for storing brought-in external PDI images in internal PACS is depicted in Figures 1 and 2. The horizontal axis indicates the occupation of the individual completing the task, while the vertical axis indicates time. In Figure 1, non-physician medical staff members store brought-in images in PACS, based on directions regarding which PDI images the physicians want imported. Figure 2 depicts processes in which all PDI images are stored in PACS by medical staff members without direction from a physician. Images stored in PACS are distributed on-demand to physicians in the hospital. Since the time of image storage in PACS is regarded as information establishment, the persons responsible for establishment in Figures 1 and 2 are medical staff members. Figure 3 provides a task process diagram in which Temporary PACS is used by medical staff to store all brought-in PDI images prior to patient examinations. Physicians can then view images stored in the Temporary PACS and subsequently store only data necessary for future treatment strategies. In this process, the physicians are responsible for information establishment.

Each process from the three task process diagrams was broken down into activity units. The results of subdivided activity units for the three processes are provided in Tables 1-3. The number of activities is largest in Workflow 1, which includes the additional activities of “select images to import,” “transmit selected images,” and “request CD delivery,” as compared with the other workflows. Workflow 3 has the second largest number, characterized by the additional activity of “issue transmission orders (store in a temporary server).” All activities in Workflow 2 are also included in the other workflows.

Within each table, activities are classified as either those carried out by a physician or those carried out by medical staff, and the time and labor costs for each activity are indicated. The total time and labor costs required were 64.1 min and ¥2161.0 in Workflow 1; 53.8 min and ¥1572.2 in Workflow 2; and 54.4 min and ¥1600.3 in Workflow 3, respectively. The cost and size for storage in PACS or a temporary PACS were ¥325.29 and 295.75 MB, ¥325.29 and 295.75 MB, and ¥185.52 and 168.65 MB in Workflows 1, 2, and 3, respectively. We found that average PDI image sizes stored monthly in PACS and Temporary PACS were 16.45 GB and 10.13 GB, respectively, showing a monthly reduction of 6.32 GB when images are stored in Temporary PACS.

The proportion of time required for each process based on the time required for

included activities is provided according to workflow in Table 4. In Workflow 1, the processes in which physicians were engaged included “view image data” and “issue importation orders,” accounting for 56.6% of the total time. In Workflow 2, the only process in which physicians were engaged was “view image data,” accounting for 36.5% of the total time. In Workflow 3, the only process in which physicians were engaged was “view image data,” accounting for 38.6% of the total time.

Figure 4 provides a comparison of total costs, physician labor costs, medical staff labor costs, and storage costs, based on the mean number of PDI images imported in our hospital per month from April 2012 to April 2015, for a total of 568 cases. Total operational costs per month were ¥1,387,183, ¥1,066,104, and ¥1,002,669 for Workflows 1, 2, and 3, respectively. Workflow 1, in which data were imported after examinations, demonstrated higher operational costs as compared to Workflows 2 and 3, in which data were imported prior to examinations. In Workflow 1, the proportion of operational costs for physicians was higher than that for medical staff, whereas in Workflows 2 and 3, the proportion of operational costs for physicians and medical staff were approximately the same. However, with regard to storage costs, the total operational cost of Workflow 3 was the lowest. The difference in total operational costs between post-examination importation (Workflow 1) and

pre-examination importation (Workflow 3) was approximately ¥321,000 per month, resulting in a reduction of approximately ¥4,614,000 per year in Workflow 3. Meanwhile, the difference in total operational costs between pre-examination importation in Workflows 2 and 3 was approximately ¥64,000 per month, resulting in a reduction of approximately ¥768,000 per year in Workflow 3. Tukey's HSD test performed using SPSS version 16 (SPSS Inc., Chicago, IL) revealed that differences in the average operating costs of the three workflows were statistically significant ($p < .0001$; Table 5).

DISCUSSION

In the present study, task process diagrams were created using UML for the three workflows used for storing brought-in external PDI images in internal PACS. By organizing each process, we were able to visualize the task processes that occurred from the time of patient visit to the storage of brought-in images in PACS. Processes were thus classified into actions such as "patient registration," "view image data," "issue importation orders," "importation of image data," "store images in PACS," and "return portable media." Our results clearly indicated that the timing of storage in PACS differs between these three workflows. In addition, the occupations of individuals carrying out data storage were

identified, and the order of task procedures was differentiated. Due to the possibility of misdiagnosis, introducing life-threatening conditions, and inducing malpractice suits as a result of using images improperly stored in PACS,[16] a responsible system operator must be designated to prevent false entry, information alteration, deletion, or mix-up of images. In addition, it is necessary to designate the person responsible for data creation so that it is clear to a third party.[31] As long as it is made clear that image information will be locked once stored in PACS, in addition to there being a clearly defined responsible creator, physicians can safely conduct medical examinations.[17] In Workflow 3, in which physicians themselves store data in PACS, the physicians are both the deciding operators and responsible creators. However, in Workflows 1 and 2, in which medical staff members store data in PACS, the deciding operator would be a medical staff member. In Workflow 1, in which a medical staff member imports data under the direction of a physician, the physician is likely the responsible creator. In Workflow 2, in which brought-in images are stored in PACS without definitive direction, it is difficult to define the responsible creator. In the event of an "oversight" other than findings related to the referral disease, the risk of litigation, in cooperation with the medical institution of the referral source, increases.[32] Workflow 2 is thus a dangerous process. This study demonstrated that Workflows 1 and 3, in which

physicians with specific medical knowledge are the responsible creators, fulfill the requirements of the guidelines and pose no issues in terms of workflows.

While the task process diagram provides simplified information that is easy to understand, it is disadvantageous in that the time required to complete each task cannot be described in detail. In order to compensate for this disadvantage, further analysis was conducted using the concepts of ABC/ABM, to assess the cost drivers of time, unit price, and number of times. From the aspect of tasks, it was revealed that in Workflow 1, the processes of viewing data and issuing an order are carried out by physicians. These processes account for approximately half of the overall tasks performed prior to storing data in PACS, which obviously places a large burden on physicians. Within this workflow, physicians receive PDI images from patients, check for viruses, browse the images using an unfamiliar viewer, and then issue an order for storage, which we believe affects other examination tasks, leading to the disadvantage of less time being available for examination.[33)] Furthermore, since Workflow 1 requires the longest time for physicians to be engaged in tasks, the operational costs are also the highest. In Workflows 2 and 3, the main task of physicians is viewing data, which places a much lower burden on them. This indicates that pre-examination importation methods can significantly reduce physician workload, as compared with the workload

associated with the post-examination importation method of Workflow 1. In addition, Workflow 1 requires the physician to use the viewer provided in the patient's PDI image CD with which he or she might not be familiar, while in Workflows 2 and 3, data are always browsed via the internal system viewer, with which the physician is familiar. With less workload and lower costs, Workflows 2 and 3 proved to be better workflows than Workflow 1.

Many of the facilities that use Workflow 2, such as the facility reported by Hagiwara et al.,[15] store all brought-in images in PACS. As such, the number of unnecessary examinations has decreased, yielding a reduction in the time required prior to treatment initiation.[34]

Although this result is advantageous to patients, it places a large cost-burden on the hospital. According to Hagiwara et al., a data storage size of 1.4 TB is required for PDI images every year, which equates to a US$5,000 expenditure.[15] There is, therefore, a need for hard disk extensions to store unnecessary images, which requires additional cost for hard disk extensions and maintenance. Hagiwara et al. have also reported that PDI images accounted for 22.8% of the entire PACS data, putting pressure on PACS capacity. Cross-Enterprise Document Sharing for Imaging (XDS-I) can solve these issues. Using this

method, the sole location where data are stored is shared, so there is no need to copy or transfer actual data. While this system is an advanced effort to share information among multiple medical facilities, it has not yet become popular due to issues such as linking patient IDs, which differ between hospitals, as well as the need for a large initial investment and operational costs.[15] Therefore, given that the capacity of PACS can be reduced by 37.5% when Temporary PACS is used, we recommend the use of Workflow 3, which is efficient not only in reducing the PDI image size for PACS but also in eliminating the risk of improper image modification.

In Workflow 3, which uses Temporary PACS, the possibility of PDI images exceeding the capacity of PACS is low. This is because physicians are allowed to store images in PACS by selecting the images necessary for future examinations or therapeutic strategies. Because images that may be overlooked are not stored, they do not take up space on the hard disk. By estimating the possible data volume during the system operational period in advance, the initial cost would only include hardware costs required for PDI Images. The monthly cost for Workflow 3 is approximately ¥64,000 lower than those of Workflow 2. While Workflow 2 has the lowest labor cost in terms of task processes, when taking into account the capacity and cost of PACS extension, the risk of appeals[22], and non-fulfillment of guideline

requirements[16-17], we believe Workflow 3 to be the best workflow.

The three workflows used in this study are part of the storing PDI images use cases introduced in the IHE Radiology Technical Framework widely used. As the use of PDI images will continue due to the high costs of the XDS-I system[15, 34-35], healthcare facilities that follow the IHE Radiology Technical Framework can benefit from our study.

Limitations

Since the primary focus of the present study was to define the timing of information establishment and to determine the responsible creator, some items that are commonly used in ABC analysis (including equipment costs, maintenance costs, space costs, and material costs) were excluded from the analysis. Moreover, although the time required to complete the same processes could differ between importation operations, the time required for each process was set to a standard length, as it was impossible to measure the times of all included processes.

Conclusion

The present study used UML, a BPM method, to determine the task processes involved in storing brought-in external images in PACS, in an effort to confirm whether or

not these processes fulfilled guideline requirements. By carrying out cost analyses using ABC/ABM, pre-examination importation using Temporary PACS was determined to be an economical and safe workflow that adheres to established guidelines.

CONFLICT OF INTEREST

None to report

REFERENCES

1) M. Ohtsuka, T. Nakamoto, M. Konishi, Y. Yamane, M. Tamura, J. Takaba, H. Sumida, K. Tanimoto, Experience of Using a Filmless System in Dental Practice at Hiroshima University Hospital, a Former University Dental Hospital, Japanese Journal of Radiological Technology 67, 673-678 **(2011)**

2) E. Yamada, K. Kishimoto, K. Kusumi, T. Kimura, A. Sawai, The Construction of a Quality Assurance System for Images in General Radiography in a Filmless Environment, Construction of an Accurate and Swift Workflow, Japanese Journal of Radiological Technology 67, 1209-1215 **(2011)**

3) T. Shibuya, K. Kato, H. Eshima, S. Sumi, T. Kubo, H. Ishida, Y. Nakazawa, Development of Image Quality Assurance Support System Using Image Recognition Technology in Radiography in Lacked Images of Chest and Abdomen, Japanese Journal of Radiological Technology 68, 422-431 **(2012)**

4) National Health Insurance Japan https://en.wikipedia.org/wiki/National_Health_Insurance_(Japan) **(2016)**

5) Integrating the Healthcare Enterprise Radiology Technical Framework, vol. 1, Portable data for Imaging,

http://www.ihe.net/uploadedFiles/Documents/Radiology/IHE_RAD_TF_Vol1.pdf, 165-174 **(2016)**

6) Moore SM, Using the IHE scheduled work flow integration profile to drive modality efficiency, Radiographics 23, 523-529 **(2003)**

7) P. M. A. van Ooijen, L. Guignot, G. Mevel, M. Oudkerk, Incorporating outpatient data from CDR into the local PACS using DICOM worklist features, Journal of Digit Imaging 18, 196–202 **(2005)**

8) P. M. Kuzmak, R. E. Dayhoff, G. Sergery, C. Greg, Maryann L. Shovestul, A. Casertano, Streamlining importation of outside prior DICOM studies into an imaging system, Journal of Digit Imaging 25, 70–77 **(2012)**

9) Channin DS, Integrating the Healthcare Enterprise, a primer. Part 2, Seven brides for seven brothers, the IHE integration profiles, Radiographics 21, 1343-1350 **(2001)**

10) Integrating the Healthcare Enterprise Radiology Technical Framework, vol. 1, Import Reconciliation Workflow.http://www.ihe.net/uploadedFiles/Documents/Radiology/IHE_RAD_TF_Vol1.pdf, 214-223 **(2016)**

11）H, Watanabe, H, Hasegawa, Data taking and management to existing system in hospital of portable medium data with another facilities, An Official Journal of the Japan Association for Medical Informatics 29, 625-626 **(2009)**

12）S. Horie, S. Akahori, Y. Matsushita, R. Takei, E. Kimura, K. Ishihara, Current issues in exchanging medical images with portable media, An Official Journal of the Japan Association for Medical Informatics 31, 647-648 **(2011)**

13）M. Harase, Virtual interview for Toyohashi Municipal Hospital, Japanese Journal of Radiological Technology Medical Informatics 16, 54–57 **(2011)**

14）T. Yamamoto, Virtual interview for Osaka Police Hospital, Japanese Journal of Radiological Technology Medical Informatics 16, 68–73 **(2011)**

15）Hagiwara H, Nemoto A, Inoue T, Burden on University Hospitals of Handling Portable Data for Imaging (PDI) Media. Applied Clinical Informatics 5, 46–57 **(2014)**

16）Ministry of Health, Labour and Welfare. Guidelines for the Security Management of Medical Care Information System, Edition 4.2 http://www.mhlw.go.jp/file/05-Shingikai-12601000-Seisakutoukatsukan-Sanjikanshitsu_Shakaihoshoutantou/0000026087.pdf **(2013)**

17）Japanese Society of Radiological Technology. Guidelines for

KAKUTEI of image information, Edition 2.1

http://www.jsrt.or.jp/data/wp-content/uploads/2012/10/Guideline_for_KAKUTEI_of_Image_Information.pdf **(2016)**

18) H. Smith, P. Finger, Business Process Management, The Third Wave, Meghan Kiffer Press **(2002)**

19) Deaming WE, Out of the Crisis. MIT Press **(1989)**

20) H. Ishii, N Ikeda, K. Ohshima, E. Taniguchi, T, Tani, Y. Yamashita, Tendency of error obtained from the classification by injection of business processes, Japanese journal of Japan Society for Health Care Management 4, 247 **(2007)**

21) K. Torii, T. Nishikawa, K. Hirano, Identification of High Risk Medical Processes and Prevention of Serious Accidents based on Incident Reports, An Official Journal of the Japan Association for Medical Informatics 27, 651-654 **(2007)**

22) H. Sakamoto, Virtual interview for Tohoku University Hospital, Japanese Journal of Radiological Technology Medical Informatics 16, 58–67 **(2011)**

23) V. Aggarwal, The application of the unified modeling language in object-oriented analysis of healthcare information systems, Journal of medical systems 26, 383-397 **(2002)**

24) M. Krol, D. L. Reich, Object-Oriented Analysis and Design of a Health Care Management Information System. Journal of medical systems 23, 145-158 **(1999)**

25) P. Staccini, M. Joubert, J. Quaranta, D. Fieschi, M. Fieschi, Modelling health care processes for eliciting user requirements. International Journal of Medical Informatics 64, 129-142 **(2001)**

26) B. JJudith, Activity-based costing and activity-based management for health care, Aspen Publishers, Gaithersburg, Maryland **(1998)**

27) S. Watanabe, S. Kaneda, Workflow Design using Activity Based Costing Management for Software Application, Proc. of the PACIS2000, 1075-1087, **(2000)**

28) Nisenbaum HL, Birnbaum BA, Myers MM, Grossman RI, Gefter WB, Langlotz CP, The costs of CT procedures in an academic radiology department determined by an activity-based costing (ABC) method, Journal of Computer Assisted Tomography 24, 813-23 **(2000)**

29) Krug B, Van Zanten A, Pirson AS, Crott R, Borght TV, Activity-based costing evaluation of a [(18)F]-fludeoxyglucose positron emission tomography study, Health Policy 92, 234-243 **(2009)**

30) Ministry of Health, Labour and Welfare.

http://www.mhlw.go.jp/toukei/itiran/roudou/chingin/kouzou/z2014/ **(2014)**

31) Hosoba M, A Proposal of the IHE Integration Profile for Image Quality Assurance and Authorization Operation Workflow in Healthcare Facility and in Case of Information Exchange using Dicom File Status Management, An Official Journal of the Japan Association for Medical Informatics 32, 245-252 **(2012)**

32) Watanabe H, Hasegawa H, The management inside hospital systems about medical certificates and images on CD-R from other institutions, An Official Journal of the Japan Association for Medical Informatics 31, 649-650 **(2011)**

33) Eric J. Lammers, Julia Adler-Milstein, Keith E. Kocher, Does Health Information Exchange Reduce Redundant Imaging? Evidence From Emergency Departments, Medical Care 52, 227-234 **(2014)**

34) Zhang J, Zhang K, Yang Y, Ling T, Wang G, Ling Y, Peng D, Grid-based implementation of XDS-I as part of image-enabled EHR for regional healthcare in Shanghai, International Journal of Computer Assisted Radiology and Surgery 6, 273–284 **(2011)**

35) K. Vivek, C. John A, M. Katarzyna J, Policies and Procedures for Reviewing Medical Images From Portable Media: Survey of Radiology Departments, Journal of the American College of Radiology 8, 39-48 **(2011)**

FIGURE LEGENDS

Figure 1. Task process of storing PDI images in PACS after examinations (Workflow 1)

Figure 2. Task process of storing PDI images in PACS prior to examinations (Workflow 2)

Figure 3. Task process of storing PDI images in PACS using Temporary PACS (Workflow 3)

Figure 4. Total and labor costs for outpatient physicians, medical staff and storage cost, per month for tasks involved in storing PDI images in PACS

Figure 1. Task process of storing PDI images in PACS after examinations (Workflow 1)

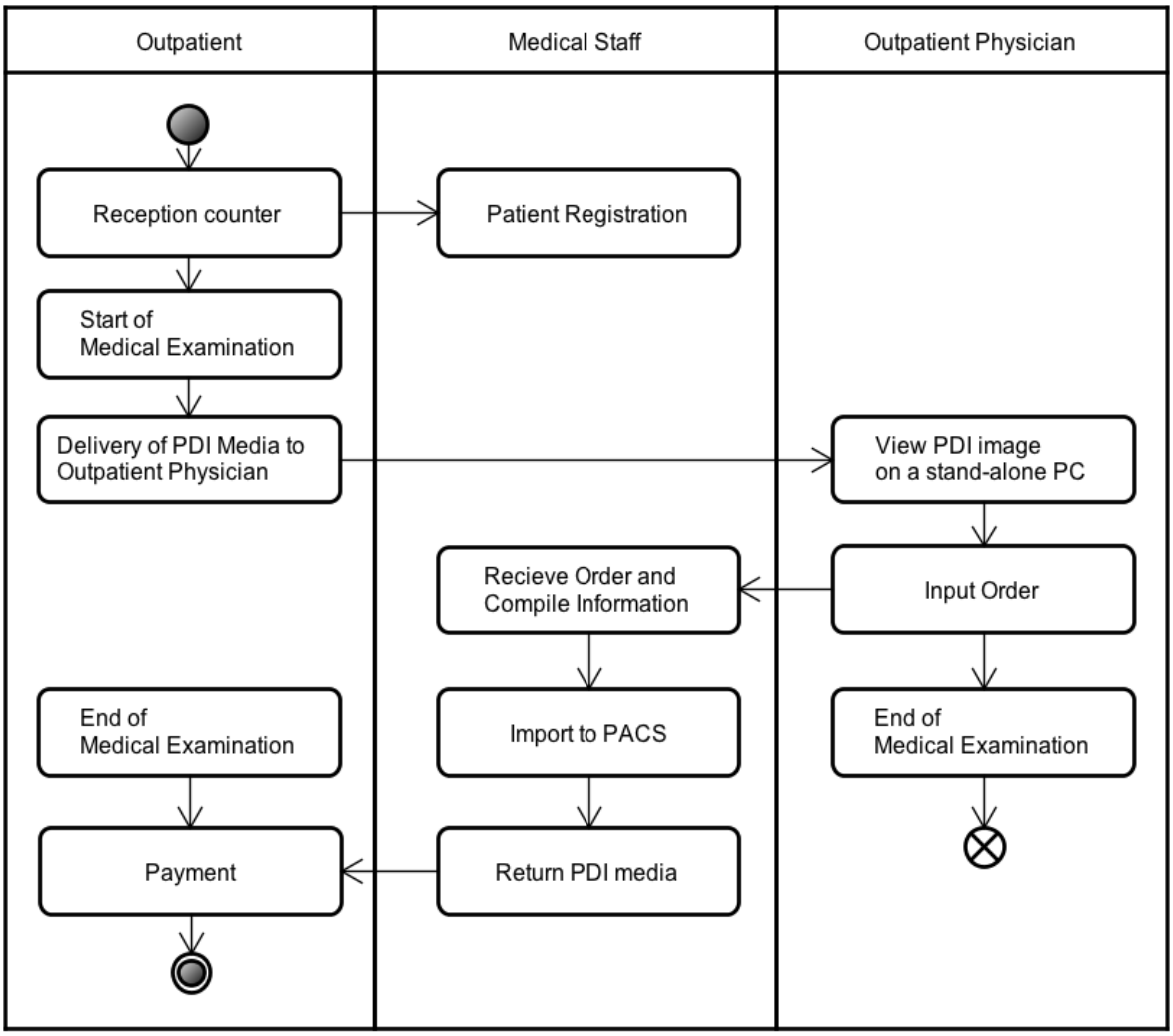

Figure 2. Task process of storing PDI images in PACS prior to examinations (Workflow 2)

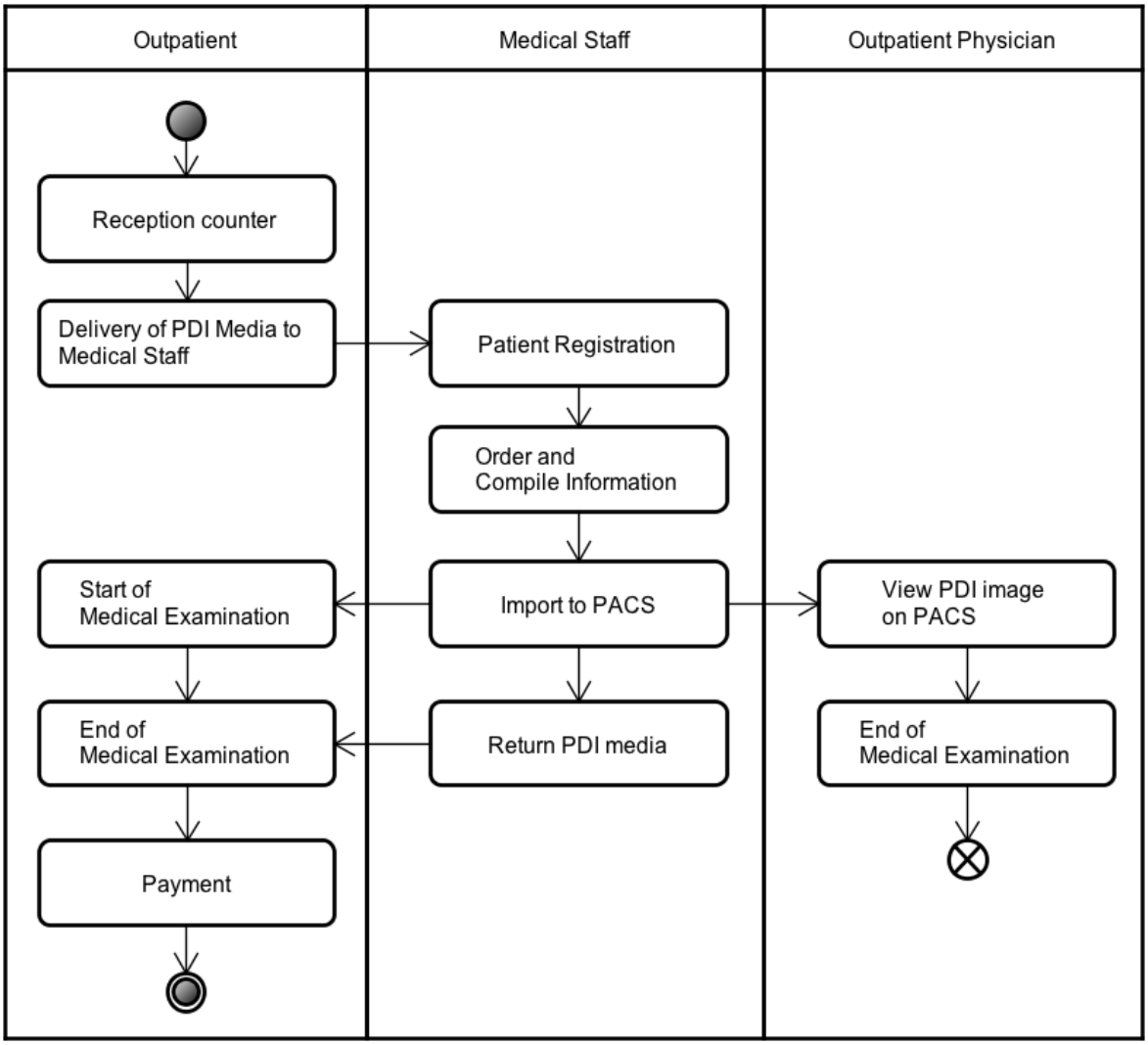

Figure 3. Task process of storing PDI images in PACS using Temporary PACS (Workflow 3)

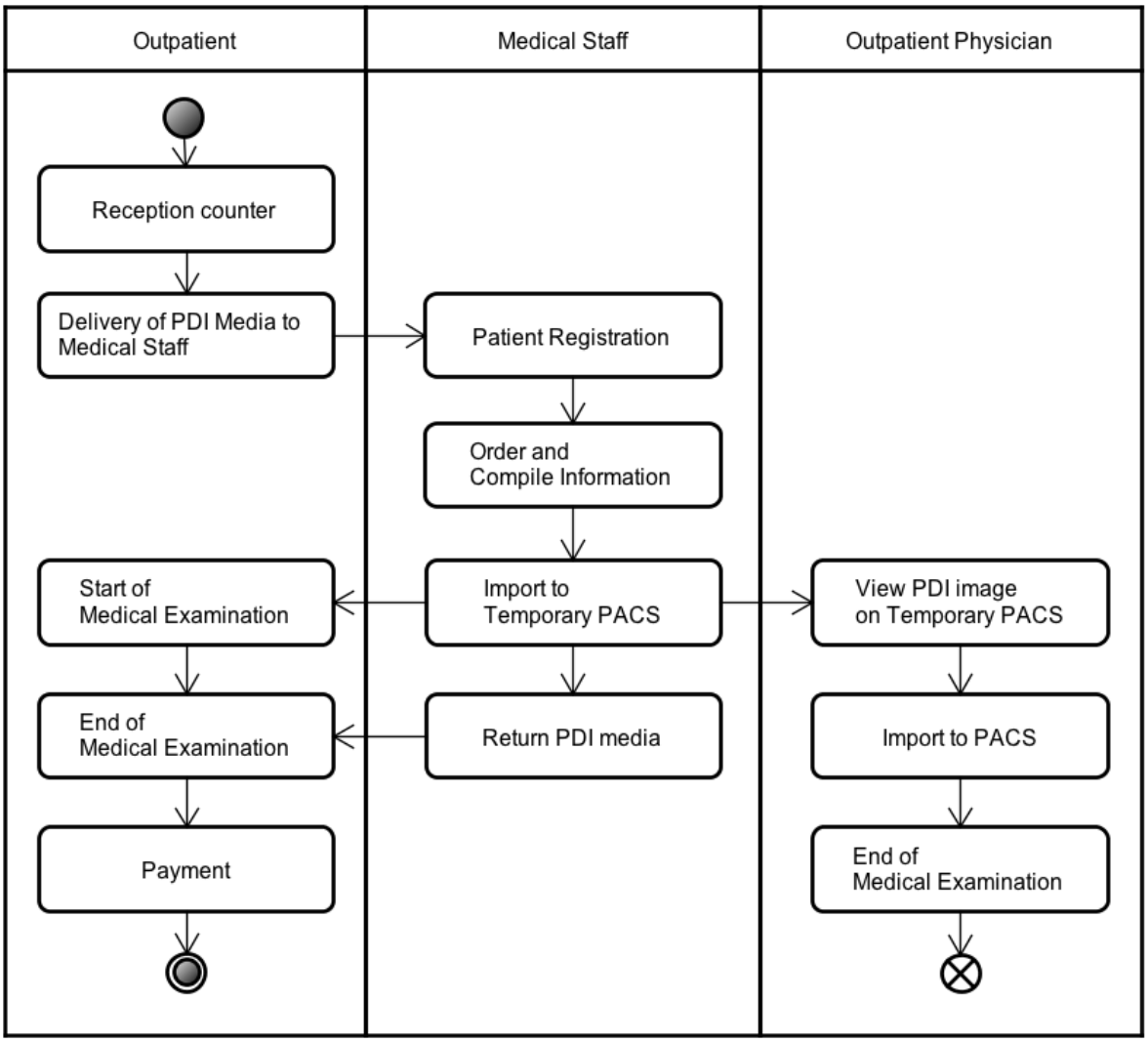

Figure 4. Total and labor costs for outpatient physicians, medical staff and storage cost, per month for tasks related to storing PDI images in PACS

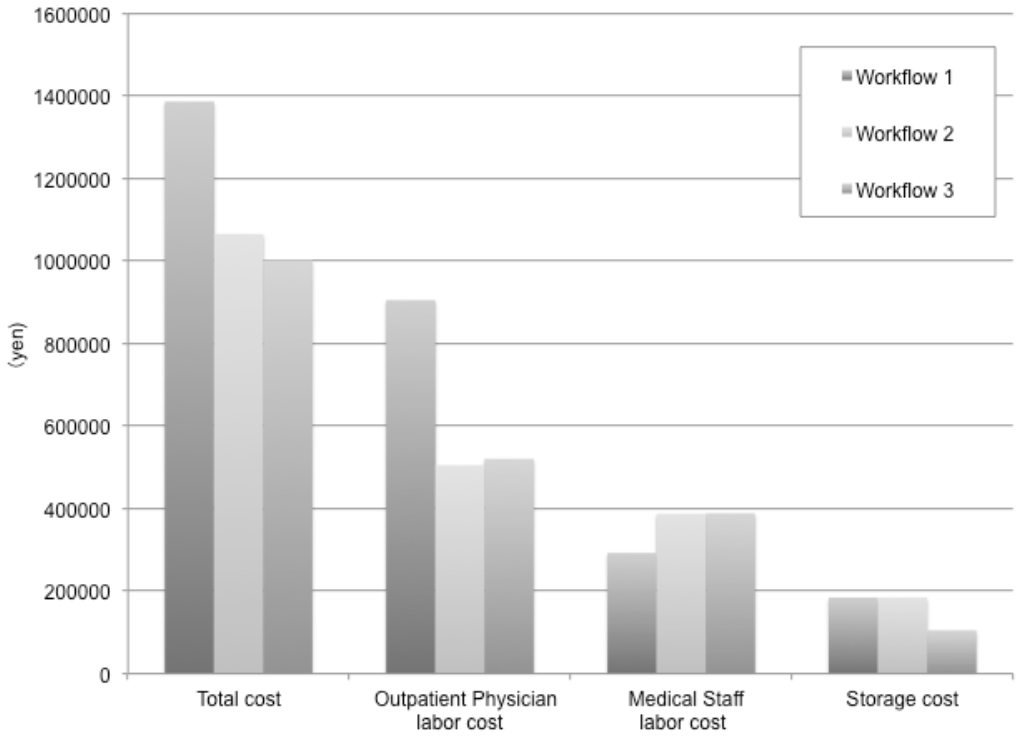

Table 1. Analysis of Workflow 1 activities

Process and Activity	Person in charge	Required time (min)	Labor cost (yen)
1. Patient registration			
Confirm insurance documents, examination application forms, and other documents	Medical Staff	1.6	33.5
Input patient information into Medical Accounting System	Medical Staff	10.9	222.1
Issue patient registration cards and deliver CD	Medical Staff	2.5	51.2
2. View PDI image	.		
Insert CD into PC	Outpatient Physician	0.5	20.9
Check for viruses	Outpatient Physician	5.0	220.0
Open viewer application	Outpatient Physician	1.4	62.6
Load images	Outpatient Physician	1.5	65.6
View images	Outpatient Physician	16.6	731.2
3 Order PDI image stored in PACS			
Select images to import	Outpatient Physician	5.3	235.4
Transmit selected images	Outpatient Physician	2.1	92.1

Enter importation orders using electronic health records	Outpatient Physician	1.1	47.9
Request CD delivery	Outpatient Physician	0.4	17.3
Inform whether CD is internally-stored or returned	Outpatient Physician	2.3	101.5
4 Compile Information			
Insert CD into PC	Medical Staff	0.5	9.7
Open importation software application	Medical Staff	0.4	7.9
Load images	Medical Staff	5.1	103.2
Change patient attributes	Medical Staff	3.9	79.6
Input orders	Medical Staff	0.4	7.8
5 Import to PACS			
Issue transmission orders (store in PACS)	Medical Staff	1.2	23.6
6 Return PDI media			
Follow storage procedures	Medical Staff	1.4	27.9
Total		64.1	2161.0

Table 2. Analysis of Workflow 2 activities

Process and Activity	Person in charge	Required time (min)	Labor cost (yen)
1. Patient registration			
Confirm insurance documents, examination application forms, and other documents	Medical Staff	1.6	33.5
Input patient information into Medical Accounting System	Medical Staff	10.9	222.1
Issue patient registration cards and deliver CD	Medical Staff	2.5	51.2
3 Order PDI image stored in PACS .			
Enter importation orders using electronic health records	Medical Staff	1.1	22.2
4 Compile Information			
Insert CD into PC	Medical Staff	0.5	9.7
Check for viruses	Medical Staff	5.0	101.9
Open importation software application	Medical Staff	0.4	7.9
Load images from CD to PC	Medical Staff	5.1	103.2
Change patient attributes in imported data	Medical Staff	3.9	79.6

5 Import to PACS			
Issue transmission orders (store in PACS)	Medical Staff	1.2	23.6
2 View PDI image on PACS			
Open viewer application	Outpatient Physician	0.9	40.6
View images	Outpatient Physician	16.6	731.2
Approve orders	Outpatient Physician	0.4	16.1
Explain internal storage of CD and request CD delivery	Outpatient Physician	2.3	101.5
6 Return PDI media			
Follow storage procedures	Medical Staff	1.4	27.9
Total		53.8	1572.2

Table 3. Analysis of Workflow 3 activities

Process and Activity	Person in charge	Required time (min)	Labor cost (yen)
1. Patient registration			
Confirm insurance documents, examination application forms, and other documents	Medical Staff	1.6	33.5
Input patient information into Medical Accounting System	Medical Staff	10.9	222.1
Issue patient registration cards and deliver CD	Medical Staff	2.5	51.2
3 Order PDI image stored in PACS .			
Enter importation orders using electronic health records	Medical Staff	1.1	22.2
4 Compile Information			
Insert CD into PC	Medical Staff	0.5	9.7
Check for viruses	Medical Staff	5.0	101.9
Open importation software application	Medical Staff	0.4	7.9
Load images from CD to PC	Medical Staff	5.1	103.2
Change patient attributes in imported data	Medical Staff	3.9	79.6

5 Import to PACS			
Issue transmission orders (store in PACS)	Medical Staff	1.2	23.6
2 View PDI image on PACS			
Open viewer application	Outpatient Physician	0.9	40.6
View images	Outpatient Physician	16.6	731.2
Approve orders	Outpatient Physician	0.4	16.1
Inform regarding storage/return of CD	Outpatient Physician	2.3	101.5
5 Import to PACS			
Issue transmission orders (only necessary images to PACS)	Outpatient Physician	0.6	28.1
6 Return PDI media			
Follow storage procedures	Medical Staff	1.4	27.9
Total		54.4	1600.3

Table 4. Time proportions required by each process in the three Workflows

	Workflow 1	Workflow 2	Workflow 3
Process	Person in charge	Person in charge	Person in charge
	Time proportion (%)	Time proportion (%)	Time proportion (%)
1. Patient registration	Medical Staff	Medical Staff	Medical Staff
	23.5	28.5	27.2
2. View images	Outpatient Physician	Outpatient Physician	Outpatient Physician
	39.1	36.5	36.5
3. Input Order	Outpatient Physician	Medical Staff	Medical Staff
	17.5	2.1	2.0
4. Compile information	Medical Staff	Medical Staff	Medical Staff
	16.0	28.1	28.6
5. Import to PACS	Medical Staff	Medical Staff	Outpatient Physician
	1.8	2.2	2.1
5. Import to temporary PACS	-	-	Medical Staff
			2.4

6. Return media	Medical Staff	Medical Staff	Medical Staff
	2.1	2.6	1.2

Table 5. Comparisons of average operating costs

		Mean difference		Significance	95% confidence interval	
(I) Workflow	(J) Workflow	(I-J)	Standard Error	probability	Lower Bound	Upper Bound
Workflow 1	Workflow 2	565.00*	9.08	.000	543.20	586.80
	Workflow 3	649.37*	9.08	.000	627.57	671.17
Workflow 2	Workflow 1	-565.00*	9.08	.000	-586.80	-543.20
	Workflow 3	84.37*	9.08	.000	62.57	106.17
Workflow 3	Workflow 1	-649.37*	9.08	.000	-671.17	-627.57
	Workflow 2	-84.37*	9.08	.000	-106.17	-62.57

*. Significant difference (P<0.05)