Efficacy of the IHE Echocardiography Connectivity within Legacy Information Systems Environment

Takeshi Ozeki*1,5 Masumi Ochi*1,5 Takahide Kohro*3,5 Aya Ebihara*3 Hitoshi Ikeda*3 Yutaka Yatomi*3 Katsu Takenaka*3 Ryozo Nagai*3,5 Yoshihiro Aizawa*2,5 Yoichi Takebayashi*4,5

The objective of this study was to evaluate the efficacy of the Integrating the Healthcare Enterprise (IHE) Echocardiography profile in an environment that included legacy information systems. For this study, we developed an Ultrasound Image and Report Management System that was capable of supporting the IHE echocardiography profile. We then implemented this system at the real clinical environment and integrated it with the existing legacy hospital information system, department system, and picture archive and communication system (PACS). A gateway interface was used to convert the proprietary protocol and data from the legacy systems to support the standard HL7 data format and DICOM connectivity used in newer systems. After a year of operation, we evaluated the efficacy of IHE connectivity by collecting questionnaires and performing interviews to compare system performance before and after the integration. The assessment showed that IHE connectivity provided greater accuracy for measurement data as well as for patient and examination information on the report. The conclusion was that IHE connectivity is effective in environments that mix new standards-based systems with existing legacy information systems.

Key words: IHE, Echocardiography, Cardiology Department Information Systems, Ultrasound PACS

1. Introduction

In recent years, advancements in electronic and information management technology have lead to advances for medical information systems, which include systems such as the hospital information system (HIS), electronic medical record (EMR), radiology or department information system (RIS/DIS), and clinical laboratory information system (LIS), have evolved independently of each other. An aging society, a lower birth rate and higher healthcare expenses are increasing the demand on hospitals to provide efficient and high quality medical service with limited resources. Therefore, effective integration of medical information systems in the hospital is important.

*1Toshiba Medical Systems Corporation, System Integration Division
*2Toshiba Medical Systems Engineering Corporation
*3Graduate School of Medicine, University of Tokyo
*4Faculty of Information, Shizuoka University
*5IHE Japan Cardiology Working Group Committee

〒140-0001 東京都品川区北品川2-32-2（六行会総合ビル）
The IHE was organized to achieve the integration of these medical information systems. The echocardiography (Echo) profile, which includes the evidence document (ED) workflow, is part of the technical framework for the cardiology domain of the IHE.

Much effort has been made in Japan to verify the benefit of IHE connectivity. However, the earlier investigations focused on the improvement of radiology workflows using Japan’s IHE radiology domain profiles. The validation of the IHE cardiology domain profiles previously has not been reported.

This study addressed the specific workflow challenges associated with performing an echo examination, including the creation and distribution of the associated report, and quality challenges of the report creation process. The echo examination workflow is more complex than previously studied radiology workflows for several reasons.

1) An echo examination consists of not only digital images, but measurement data and a report in natural language.

2) Stress echo is a multi-stage examination with images and data obtained before and after exercise or pharmacological stress.

3) Ultrasound diagnostic imaging equipment is portable and is not always connected to the network.

In Japan, the JAHIS (Japanese Association of Healthcare Information Systems Industry) specifies the use of the JJ1017 standard for data exchange. However, this standard was not introduced until 2001. HIS, RIS/DIS, and PACS systems installed before 2001 do not support JJ1017. In fact, many hospitals in Japan still use proprietary ordering codes instead of the JJ1017 standard.

Although the international IHE technical framework uses only DICOM and HL7 standards, the prior IHE validations in the radiology domain of Japan additionally included use of the JJ1017 standard. However, to address the needs of Japan’s existing legacy systems and to comply with the broader international interpretation of “IHE connectivity”, this study required the use of HL7 and DICOM standards only.

In this paper, we describe the implementation of an ultrasound image and report management system within a legacy environment including a HIS ordering system which was implemented before the JJ1017 standard was introduced. We also discuss the information obtained from the system's users through interviews and questionnaires. Finally, we review results showing the efficacy of IHE connectivity in this mixed environment.

2. Background

1) Legacy Echo Workflow

Historically, HIS, EMR, RIS/DIS, and PACS systems ran independently of each other. Information in one system was not accessible to another one.

Prior to connecting the systems electronically, the ordering process in the hospital was handled using handwritten information on paper. The process started with filling out an ordering form with the patient and procedure information for the ultrasound examination. After scheduling the examination at the reception desk in the ultrasound laboratory department, the date and time for the procedure was written on the form. Using the handwritten information from the order form, the receptionist also recorded the appointment for the ultrasound diagnostic imaging equipment in the paper ledger that was used at the reception desk to track patient arrival. The patient then was given an appointment form and taken to the examination waiting room. Throughout the process, handwritten information increased the risk of mistakes that caused rework for the schedule and longer waiting time for the patients.

During the ultrasound examination, ultrasound...
images were recorded on thermal printer paper and video tape. These physical media made the processing of information cumbersome. The images on the thermal paper had to be cut out and pasted into the examination report. The video had to be labeled and stored. Searching for the cassette and forwarding the videotape to the examination’s location was time consuming and the time wasted on these mundane tasks was significant and reduced the time available to spend with patients.

Following an examination, technicians or physicians created a handwritten report by reviewing the images on the thermal printed paper or the recorded videotape and measurements made during the examination were transcribed from information recorded on the media. The task was time consuming for the healthcare service providers and mistakes could be made easily while transcribing the information.

2) IHE Guidelines

The IHE guidelines for integrating information in the ultrasound laboratory department specify that all study information must be associated with an order and a results report. Linkage of the information together is important for creating the EMR which is accessible in the HIS. The IHE echo profile specifies the ideal use case for the examination workflow.7

The workflow shown in figure 1 identifies the various system functions (called actors) for the IHE Echo and ED integration profiles.

3. Approach

1) Digital Ultrasound Image and Report Management System Design

The ultrasound image management system must manage not only the single- and multi-frame image data using the DICOM standard protocol but also the measurement information made during the examination. Measurement data, which include the name of the measurement item, a measurement value and the units of measure, can be transmitted from the ultrasound diagnostic imaging equipment via the DICOM SR (structured reporting) standard6,10. While newer ultrasound diagnostic imaging equipment may be capable of creating measurements in the DICOM SR form, most of the older ultrasound diagnostic imaging equipment found in hospitals today is not capable...
of fulfilling the requirements of the EC actor. Therefore, there is a shortage of equipment that can be used to perform examinations that require measurements to be taken.

Moreover, it is also important to be able to confirm measurements made during an examination. Workstations which function to review a digital examination can also act as the evidence creator providing the same measurement functions as the ultrasound diagnostic imaging equipment. This feature can be used to improve the utilization of the ultrasound diagnostic imaging equipment. Concentrating the use of the imaging equipment on image acquisition and conducting the measurement and analysis of the examination during post-processing at the display workstation provides a more efficient workflow.

The structured report object for the ultrasound data can be transferred in four different ways: 1) Basic SR, 2) enhanced SR, 3) comprehensive SR, and 4) private SR. The echocardiography DICOM SR template is number 52004.10.

Although the structure of an ultrasound examination report is defined as a standardized file format, the content is not defined in a standardized fashion, so that each hospital tailors the content to use unique terminology for its reports. The measurement items used in a report also differ from hospital to hospital. Implementing unique terminology and measurements for each hospital requires customization of the reporting system.

2) Implementation

In introducing the IHE-compliant system at the University of Tokyo Hospital, the goal was to eliminate the mundane task related to paper, videotape and handwriting, while preserving the familiar workflow for report creation and distribution. To increase acceptance of the system, the reporting system was customized to match the content used within the legacy handwritten reports. The system was designed to maximize the capabilities of the integrated system and minimize any limitations it introduced. The gateway interface was used to convert the proprietary protocol and data format from the legacy systems to support the standard HL7 data format and DICOM connectivity used in newer system. In order to achieve this objective, the registration function was enriched to provide the flexibility to edit the print layouts. Customization of the reporting system was simplified so the hospital’s system administrators could easily adjust the format for findings and measurements. The completion of the installation and started to operation of the system was in June 2007. An example of the print layout for a cardiology echo examination is shown in Figure 2.

3) Workflow

The system connectivity around the ultrasound image and report management system at Tokyo University Hospital is shown in Figure 3.

The HIS uses admission, discharge and transfer (ADT) messages and order placer (OP) functionality to create and transmit the order for an echo using HL7 v2.3. The order for the ultrasound examination procedure, which includes the patient information, is transmitted to the ultrasound laboratory department system which handles departmental scheduling and order filling functions (DSS/OF) using standard messages based on the IHE Echo profile.11

At Tokyo University Hospital there are a total of 19 sets of ultrasound diagnostic imaging systems which function as acquisition modalities (AM) connected to the network, including 8 sets for cardiology uses and 8 sets for the abdominal uses, 2 sets for vascular and 1 set for physical check-ups. The patient and examination information is queried and retrieved by the ultrasound diagnostic imaging equipment from the ultrasound laboratory department system using the modality work list management (MWM) service class of DICOM. At the start and end of the ultrasound examination, the status of the examination is sent to
the ultrasound laboratory department system from the imaging equipment using the modality performed procedure step (MPPS) service class of DICOM. After the ultrasound examination is completed, the multi-frame ultrasound image data acquired by the acquisition modality are transmitted to the ultrasound image management system to be stored using the DICOM store service class.
The data is then forwarded to the PACS for long-term archive of the examination.

The flow of information from the patient’s arrival at the ultrasound laboratory to the creation and distribution of the ultrasound report is shown in figure 4. The ultrasound image and report management system is the central component of the information flow.

Additionally, for patients who have pre-ordered and pre-scheduled examinations within the hospital information system, their arrival at the ultrasound laboratory room can be confirmed by reading the hospital card carried by out-patients, or by scanning the barcode on the patient’s wristband for in-patients.

Once the ultrasound examination registration card is issued by the ultrasound laboratory department system at the ultrasound laboratory reception desk, the barcode on the registration card can be read at the diagnostic ultrasound imaging system so that the patient’s examination information can be queried and retrieved from the modality work-list management (MWM) server. This eliminates manual entry of patient and examination information at the diagnostic ultrasound imaging system. Scanning of the barcode can also be used to bring up previous reports or examination images for the applicable patient. Prior studies are retrieved from the server managing the ultrasound images and reports and reviewed at the workstation to facilitate comparison of previous cases while reviewing the current case and generating the associated report.

Based on the examination order that was registered in the laboratory department system, the sonographer or laboratory technician performing the examination opens a preliminary examination report. The report is then populated following these steps: 1) check the acquired images from the examination, 2) confirm the patient information, 3) select the image to be used as evidence in the report and add annotation comments on the image, 4) if necessary, check the measurement values which are read from the structured report template, 5) input physical findings, 6) check the report and send what has been created to the report server as the interim report documenting this initial work. Later, the physicians at the
ultrasound laboratory department review the technician’s report. If necessary, they make corrections then they approve the report after adding their comments. The approved report is then registered into the web server supporting the ultrasound laboratory department system. The approved report is stored in a PDF format which supports the IHE displayable report (DRPT) function. Therefore, once the physician has approved the report, the final approved report cannot be modified, but viewed only. The URL of the final report is linked to the EMR, making the report viewable from the HIS.

4. Evaluations

We investigated the efficacy of the report creation and approval process before and after the system had been installed and integrated with the legacy systems at Tokyo University Hospital. We also evaluated the quality of the reports. A questionnaire was filled out by the technicians and physicians who created reports, as well as the physicians who reviewed and approved them, and performed on July 2008. There were 10 questions for the report creators and 9 questions for the report approvers. Each questionnaire contains the multiple choice with the form of choosing one from 5 choices (improve, slightly improve, no change, slightly deteriorate, and deteriorate), and free text form for the detail explanations. The questionnaire assessed the following items.

1) Accuracy of the patient information on the report
2) Accuracy of the examination ordering information on the report
3) Accuracy of the measurement data on the report
4) Efficiency of the report creation/approval process
5) Quality of the report

5. Results

There were 38 questionnaires collected in total, with 23 (10 technicians and 13 physicians) collected from individuals who created reports and 14 (all physicians) who ordered ultrasound examinations and reviewed cases to approve the associated report. The results from the questionnaire are summarized in figure 5.

1) Accuracy of the patient information on the report: For 58% of report creators and 60% of approvers, the accuracy of the patient information improved. By following the IHE Echo profile guidelines on how to enter and share patient information between systems, the rate of errors in the patient information was reduced (shown in the patient information part of the figure 5).

2) Accuracy of the examination ordering information on the report: For only 29% of report creators and 33% of approvers, the accuracy of the ordering information improved. Despite using the IHE echo profile guidelines to add integration and coordination with other systems, only minimal improvements were made in the order information.

3) Accuracy of the measurement data on the report: For 42% of report creators and 53% of the report approvers, the accuracy of measurements improved. As shown in the measurement part of figure 5, the remaining 58% of report creators and 47% of report approvers said they saw no change at all. The change from manual to electronic report creation had some positive and no negative effects on the accuracy of measurements in the report.

4) Efficiency of the report creation/approval process: The efficiency of creating reports increased for 58% of the report creators. For 25% of the report creators, efficiency did not change and for 17% a decrease was noted. Although functionality had been added to permit measurement values to automatically populate a report using
the structured results (SR), only some of the diagnostic ultrasound imaging systems supported the IHE evidence document (ED) profile guideline. Comments on the survey indicated there were many diagnostic ultrasound imaging systems which did not allow measured values to be transmitted. Improvement was not possible because the equipment did not support the feature. Those that felt the efficiency had decreased noted that it was harder to notice errors on the reports with system-populated measurements than when measurements were hand-written.

5) Quality of the report: For 77% of the report creators and 47% of the report approvers, the quality of the electronic reports was better than the quality of reports produced within the legacy system. For 17% of the report creators and 53% of the report approvers, the quality of the reports had not changed. Only 4% of the report creators felt the report quality had decreased due to user interface issues for the reporting system and response time for accessing prior examination images or reports and addressing these issues would eliminate the quality issues. The report quality results are shown in the quality part of the figure 5.

6. Discussions

Even in a mixed environment where new information systems interface with legacy ones, following the IHE connectivity guidelines can improve workflow for report creation, raise efficiency for examination reviewing and approval, and improve the quality of reports being generated. Implementing IHE–based connectivity also can provide the following benefits to cardiologists, technicians, and patients.

The benefits for the cardiologist are; 1) providing echo measurement interoperability, 2) ensuring images and measurements are securely stored, and 3) reducing the report creating time.

The benefits for the technicians are; 1) automatically obtaining correct patient and procedure information, 2) verifying that all images obtained, even on the mobile systems, are securely archived prior to deletion.

The benefits to patients are; 1) removing the need to wait while patient information is entered into the ultrasound diagnostic imaging system and old reports or images are pulled, 2) enabling better patient care because the interpreting physician can more accurately access interim changes.
The measurement data interoperability will lead to the benefit to all that the measurement data: 1) can be shared between the healthcare institutions or hospitals, 2) can be used even the equipment or system was replaced with new one because of the DICOM and DICOM SR were used.

The remaining factors limiting the efficiency and usefulness of IHE connectivity are associated with user interface challenges and the high number of ultrasound systems that do not yet support the DICOM SR feature needed to send measurement data.

System manufacturers need to design user interfaces that help eliminate data entry errors and improve procedure documentation capabilities. Applying IHE connectivity cannot address ordering information accuracy issues resulting from interface shortcomings. The reason of the only minimal improvements could be made in the accuracy of the order information on the study were: 1) only a small number of physicians provide the detailed information needed when creating an order, 2) restrictions on the number of characters available for the order input area prevent the needed information from being entered, and 3) the order input process is not simple. According to the comments on the questionnaire, items 2 and 3 were attributed to user-interface problems with the function in the HIS used to place orders. Also, the ultrasound report system needs freehand drawing capability to permit a schematic to be drawn in the report to describe the interpretation of findings from the examination images. A carefully selected input device that allows users to make precise pictures comfortably and easily would improve the quality of the report and make report creation more efficient.

The number of ultrasound imaging systems that support the DICOM SR feature to send measurement data will increase over time. Support of DICOM SR should be a requirement for all replacement equipment.

Furthermore, of growing importance, reports using SR have the potential to contribute data that can support secondary uses for statistical analysis and clinical data research. This is especially true for cardiology reports because they include many measurements taken during the examination or made on the images after the examination. Measurements are an essential part of an echo report. Transmitting and storing these measurements as numerical data with the associated images, not just as graphical data on the images, makes it possible for these critical numbers to be analyzed further. Storing the data in a meaningful way that preserves the value, units of measure and linkage that show where these measurements were made, will open many new research possibilities. The cardiology committee of IHE-Japan has recently launched a sub-working group committee called “Data Handling (or Harvesting)” (DH) to identifying what cardiology data needs to be collected and how it should be collected to support the different types of secondary use cases. The committee will publish a draft white paper for the future IHE cardiology data handling profile. Some of the authors of this study are involved in this new IHE sub-working group activity. The group will start by examining catheterization procedure data then will address echocardiography data, next.

7. Conclusion

This study showed that it is important to integrate systems using the IHE connectivity guidelines, even when integrating with legacy systems. Eventually, legacy systems can be replaced with new systems and if the replacement systems support IHE profiles then it will not be necessary to use gateway converters or to support proprietary protocols and data formats. In this study we developed the ultrasound image and report management system. Then, we implemented the system,
integrating it with the existing legacy HIS, department and PACS systems. We used HL7 and DICOM standards and followed the IHE Echo and ED profile guidelines. However, since some of the legacy systems did not support standards-based connectivity, we used a gateway interface to convert the proprietary protocol and data formats to read and store data. Finally, we evaluated the system in terms of procedure performance efficiency and report quality.

Our analysis showed that implementing a system that operated according to the IHE echo and evidence document profile specifications improved patient care, reduced manual entry errors and eliminated unnecessary work in the ultrasound laboratory department. This suggests that future implementation of IHE–compliant systems across the hospital may improve the overall quality and efficiency of the healthcare provided.

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Reference