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Interoperative fundus image and report sharing in compliance with integrating the healthcare enterprise conformance and web access to digital imaging and communication in medicine persistent object protocol

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Foundation item: National Natural Science Foundation of China (No.81271668)

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Received: 2013-07-16 Accepted: 2013-08-18

Abstract

• **AIM: To address issues in interoperability between different fundus image systems, we proposed a web eye-picture archiving and communication system (PACS) framework in conformance with digital imaging and communication in medicine (DICOM) and health level 7 (HL7) protocol to realize fundus images and reports sharing and communication through internet.**

• **METHODS: Firstly, a telemedicine-based eye care work flow was established based on integrating the healthcare enterprise (IHE) Eye Care technical framework. Then, a browser/server architecture eye -PACS system was established in conformance with the web access to DICOM persistent object (WADO) protocol, which contains three tiers.**

• **RESULTS: In any client system installed with web browser, clinicians could log in the eye-PACS to observe fundus images and reports. Multipurpose internet mail extensions (MIME) type of a structured report is saved as pdf/html with reference link to relevant fundus image using the WADO syntax could provide enough information for clinicians. Some functions provided by open -source Oviyam could be used to query, zoom, move, measure, view DICOM fundus images.**

• **CONCLUSION: Such web eye-PACS in compliance to WADO protocol could be used to store and communicate fundus images and reports, therefore is of great significance for teleophthalmology.**

• **KEYWORDS:** picture archiving and communication system; teleophthalmology; integrating the healthcare enterprise; web access to DICOM persistent object

DOI:10.3980/j.issn.2222-3959.2013.06.24

Wu HQ, Lv ZM, Geng XY, Jiang K, Tang LM, Zhou GM, Dong JC. Interoperative fundus image and report sharing in compliance with integrating the healthcare enterprise conformance and web access to digital imaging and communication in medicine persistent object protocol. *Int J Ophthalmol* 2013;6(6):879-883

INTRODUCTION

Diabetic retinopathy (DR) is one of common complications for those patients with diabetes. If suffered, the patients should take fundus eye examination every 6 months or a year. As recommended by clinical guidelines, early eye fundus image screening could prevent visual disorders [1]. A national DR screening project held in UK for those patients over 12 years reached good preventive effect but with high cost paying for examinations[2].Li *et al*[3] performed a cost-effective analysis on tele-consulting for fundus image and conventional fundus examination, suggesting that DR screening based on telecommunication is more economic. Recent advances in web-based picture

archiving and communication system (PACS) enable the realization of teleophthalmology for DR screening. However, relative diagnostic reports attached to fundus images are stored in isolated workstations, lack of interoperability [4]. Therefore, we proposed a web eye-PACS framework in conformance with digital imaging and communication in medicine (DICOM) and health level 7 (HL7) protocol and implemented it based on some open-source softwares to realize fundus images and reports sharing and communication through internet.

MATERIALS AND METHODS

Eye Care Work Flow Integrating the Healthcare Enterprise (IHE) Eye Care Workflow defined three scenarios, namely standalone eye care clinics, large eye care groups and hospital-based eye care departments [5]. The IHE Eye Care Workflow Integration Profile establishes the continuity and integrity of basic patient and procedure data in the context of an eye care clinic and/or an integrated hospital workflow scenario. However, other scenarios such as eye care referrals, telemedicine are not being formally addressed and will be considered in future versions. In our study, we proposed a telemedicine-based eye care work flow (Figure 1), that is, clinicians perform an acquisition of fundus images from patients in the rural areas, and the images were transferred to ophthalmologists for diagnosis through internet, who interpret the images and produce a DICOM structure report (SR) including reference to some significant images. Following the Integration Profile, we dealt specifically with consistent handling of patient identifiers and demographic data. For this purpose, a reliable image management system which could support subsequent workflow steps, such as reporting, is needed. It also provides the ability for the acquisition devices (such as diagnostic imaging, measuring, test equipment) to identify actual procedures that were performed.

System Configuration We built up eye-PACS system based on browser/server (B/S) architecture, in conformance with the WADO protocol, which contains three tiers. The client tier includes all different types of Web browsers supporting any request for access to middle-tier services. The client tier is implemented by desktop, laptop, and tablet PCs capable of running a Web browser and Java middleware applications such as the Java 2 runtime environment (J2RE). The server tier interacts with the data tier through open database connectivity (ODBC) protocol and providing the client tier with services through HTTP/HTTPs protocol. The dcm4chee server was used to provide the web access to DICOM persistent object (WADO) service to Web clients, to process service requests coming from the client tier, and to

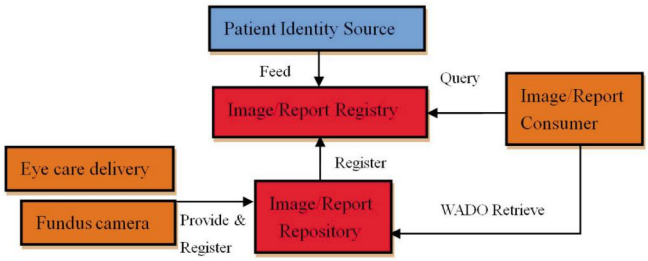

Figure 1 Work–flow chart for remote eye care.

respond properly, providing clients with all necessary information through dedicated interfaces. The components handling the WADO service access rules and communication were also deployed in the server tier. In this study, the dcm4chee server was utilized on Window XP operating system as application Server. The JSP processing environment, the runtime engine, and the servlet engine, were integrated into a Java-2 Enterprise Edition (J2EE) Container. Web cache and HTTP server are also integrated into the application server to support the operation of WADO applications within the Web environment. The data tier comprises the DICOM archives, including databases for study, series, and images. The database used in our study was MySQL database management system (DBMS). The archive server was developed on a system based on an Intel Pentium IV 3.2GHz with 2GB of RAM, 250-GB hard disk, and the Windows XP operating system.

Viewing Fundus Images and Reports Through Web Access to DICOM Persistent Object The WADO service, implemented as an HTTP script, builds a DICOM FIND message and retrieves the image form the DICOM server. Example of WADO GET request of image and report, studyUID&seriesUID&objectUID&frameNumber, in which studyUID is the unique identifier (UID) of the study containing the object (s); seriesUID is the UID of the series containing the object (s); objectUID is the UID of the single object (Service Object Pair SOP); frameNumber is the number of the selected frame. It creates the HTTP response body as a multipurpose internet mail extension (MIME) part. It's commonly presented as the link references to external observations such as instance, series and study UIDs as different ID sets, and path of the DICOM system in the reference. The object was displayed on the Web browser of the client without the support of any middleware software, in case of an image in jpeg/gif format or a structured report in html/txt format. In this study, the eye-PACS application server dcm4chee was in conformance with WADO protocol, and another open-source web DICOM browser Oviyam was used to query patients' list. In any client system installed with web browser, clinicians could log in the eye-PACS to observe fundus images and reports.

Digital Imaging and Communication in Medicine – Structured Report Template for Fundus Images

DICOM SR is proposed in DICOM3.0 with its own information object definition (IOD). Three SR templates have been given for developers, namely basic text SR, enhanced SR, comprehensive SR. SR structure is tree-like, with flexible tree points for different report usage, which could contain images, waves and other complex objects for measurements and computer aided diagnosis. In this study, enhanced SR with reference to image was used.

RESULTS

In our study, we logged in the website through PC, laptop, mobile phone with different operating systems and could visit fundus images as well as related reports conveniently (Figure 2). Some functions provided by Oviyam could be used to retrieve, query, zoom, move, measure, and view DICOM fundus images.

WADO handles the information entities (IEs) of study, series, and persistent object, which is the information class related to the image content of the composite object. A UID is allocated to any instance of the earlier IEs. The WADO service standardizes Web access to objects, over HTTP or HTTPs (secure HTTP) protocols. It enables a Web Client System to retrieve objects, which are managed by a web-enabled DICOM Server. In this study, Query parameters were sent to the dcm4chee through HTTP GET method request. The client could also request the dcm4chee to convert the object to a different, presentation-ready format, *e.g.* jpeg for images and html for reports. In this study, we visited fundus images and reports with GET request using WADO-type HTTP GET method as follows:

http://222.192.61.40:8080/wado?requestType=WADO& studyUID=2.16.124.113543.6021.1.1.697369234.6232.1356080324.9 &series UID=2.16.124.113543.6021.1.2.697369234.6232.1356080324.10&objectUID=2.16.124.113543.6021.1.3.697369234.6232.1356080329.11

http://222.192.61.40:8080/wado?requestType=WADO&studUID=0&seriesUID=0&objectUID=1.2.276.0.7230010.3.1.4.2155604110.4180.1021041295.10&contentType=text/html

In this study, MIME type SR was saved as pdf/html with reference link to relevant fundus images using the WADO syntax. The images and reports in the repository were sent to browser, and viewed as a complete SR (Figure 3).

DISCUSSION

Web-PACS have been widely utilized in different biomedical departments. Dijk *et al* [6] described two different IHE-XDS (-I) solutions based on a network that facilitates the transmural exchange of documents as well as images. With that document, cardiologists from different centers could share the information regarding a patient, before as well as after a therapeutic invasive procedure. Lee *et al* [7] adopted XDS-I integration profile into the molecular imaging data design in preclinical imaging informatics systems as in enterprise PACS application. However, it is still in its infancy in department of ophthalmology. The eye-PACS system presented in this article was experimentally proved to be of usability in eye care organization, and the further application in clinics should be tested.

IHE Eye Care is one of the 11 clinical and operational domains, each domain is organized into two committees: technical and planning. The technical committee researches and profiles the use of standards to address each use case, documenting them in domain-specific technical framework documents and their supplements. The current web browser could only show the images in jpeg, bmp but not DICOM formats. The national electrical manufacturers association (NEMA) and the international organization for standardization (ISO) accepted the WADO service for Web distribution and display of medical images because of the limitations of point-to-point DICOM transfer syntax. The WADO service is specified in the Part 18 extension of the

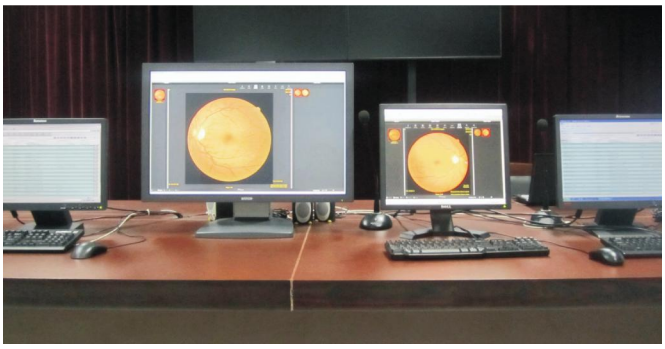

Figure 2 The connected eye-PACS system in our laboratory.

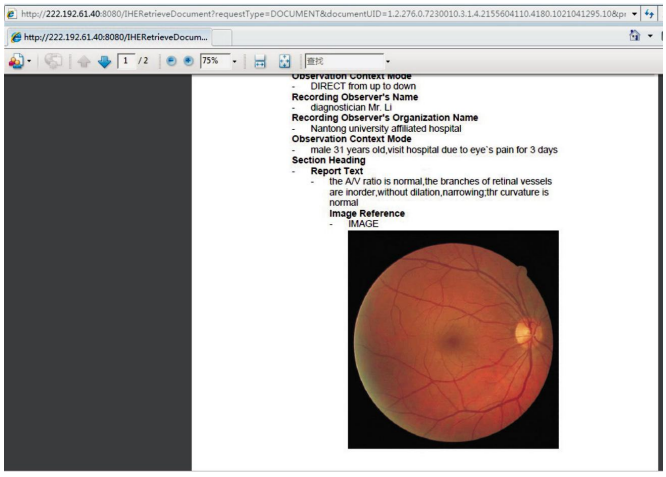

Figure 3 DICOM SR diagnostic imaging reports include nested container content items.

DICOM standards[8]. WADO is standardized by both DICOM (WG10) and ISO (TC215/WG2) organizations as NEMA04a and ISO04c standards, respectively. WADO is neither a new medical communication protocol nor the transformation of a compatible DICOM service into its Web equivalent. It is a new alternative service for accessing and presenting "DICOM persistent" objects (images, waveforms, reports, *etc.*) through Web protocols, without requiring DICOM compatible clients. Moreover, it is a simple demonstration mechanism, through Web pages or extensible markup language (XML) documents, using DICOM UIDs. Besides WADO protocol, Koutelakis and Lymberopoulos [9] proposed a WADA service model and proved its effects in PACS.

WADO has also been inserted into other medical information exchange standards/profiles, such as the integrating the IHE XDS-I integration profile, as a retrieve service [10]. In 2004, XDS profile has been released by IHE, which defines the sharing and exchange of the information during health care delivery in different isolated clinical affinity domains. The IHE XDS, defines the document registration, query and extract with ebXML standard and specifically it's XDS-I extension (for images), seems to be the most promising attempt for an integrated medical image sharing standard[10-12].

IHE strengthens the communication between DICOM and HL7 with different Actors and Transactions based on messages. In this process, report sharing is essentially practical. The clinical document architecture (CDA) is stored into electronic medical record (EMR) or electronic health record (EHR) databases. A clinician consults the CDA using the reference completed by the WADO parameters, and clicks on one image link to observe the image. DICOM SR and HL7 CDA diagnostic imaging report Transcoder is a necessity for health information exchange. For automated transformation of DICOM SR diagnostic imaging report, it is recommended to transform only SR documents where the DICOM completion flag value equals "COMPLETE" to make sure that only SR documents get exported that contain all significant observations. The CDA diagnostic imaging report implementation guide (HL7 CDA R2 DIR IG, R1-2009) defines constraints on CDA Header and Body elements used in a diagnostic imaging report document. In our result, the part of Section.text contained the narrative text (attested content) of the document. Section.text is populated from DICOM SR content items of the original document in a way that the full meaning could be conveyed in an unambiguous manner by applications that render the document. Structured CDA entries may be referenced within the narrative section text of the CDA document. Parts of the structured body of the CDA document that are part of the attested content of the document shall be included in the narrative section text. To that end corresponding CDA entries are extended by original text elements and reference values that can be derived from the entry act class code display name[13].

EyeCare Evidence Documents (ECED) define image manager and archive, acquisition modality, evidence creator, image display, in which evidence creator is a system that creates additional evidence objects such as derived images or measurements, and transmits them to an image archive like EHR. MIME type of the object contained in the contentType parameter, compatible the <accept> parameter of the GET method referencing an image or a report from an EHR including references to images, providing access by outside referring doctors to a hospital web server that contains references to reports, images and providing access to anonymized DICOM reports, images *via* a web server, for teaching purposes and for clinical trials. DICOM SR numeric measurements (value type NUM) are mapped to the quantity measurement act class. The quantity measurement act class is associated with one or more SopInstance act classes. SopInstance is associated with zero or one purpose of reference act class through the reason entry relationship, which is of significance for further data mining and computer aided diagnosis system. Using a ontology to search, Lin and Liou[14] analyzed the SR to retrieve key words and found the related medical image documents when getting a SR or DICOM image, reducing the time for searching and improve the diagnostic accuracy, when radiologists write or read reports and images.

Teleophthalmology is of great importance in eye care because of its convenience and cost-saving [15]. Kurji *et al* [16] performed a questionnaire study in Africa and found that diabetic patients preferred a teleophthalmology based screening over a traditional ophthalmologist-based screening. Similar study result was observed in India [17]. Nowadays, with the population of electronic health record(EHR), fundus image is essential part of the EHR for its importance in chronic disease follow up and the standards for its storage and communication has been proposed [18,19]. Pandit and Boland [20] have proved the impact of EHR on an ophthalmology practice. In our previous studies, we have implemented an EHR system containing about 5 million local citizens' health information, and we will add fundus image information into the system in the future.

In short, the web eye-PACS in compliance to WADO protocol could be used to store and communicate fundus images and reports, therefore is of great significance for teleophthalmology.

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