Tele-consulting for Collaborative Diagnosis and Care of Heart Malformations

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Abstract

Medical cooperation with clinical centers of Balkan Countries was developed by the "G. Pasquinucci" Heart Hospital of "G. Monasterio" Foundation in Massa, with the support of the "Heart World" Association and the Tuscany Region, in diagnosis and care of congenital heart malformations. Given the geographical scenery it was important to set up a tele-consulting network over the Internet for multi-center collaborative medical-decision making. Tele-echocardiography was implemented in pediatric or gynecology centers of Croatia, Bosnia-Herzegovina and Albania, using videoconference equipment for transmitting on-line over the Internet diagnostic images. Limitations of commercial solutions suggested exploitation of Open-Source technology to set up low-cost devices implementing both live and store-and-forward tele-consulting as well as videoconference and image storage/management.

1. Introduction

Information and communication technology have provided a foundation for telemedicine breaking down geographical barriers and providing specialized medical care virtually anywhere in the world [1]. Telemedicine applies to diagnosis, consulting and transmission of medical data, signals or images. Tele-consulting usually involves the transmission of medical images over the network, serving multi-center, collaborative medical decision-making in diagnosis and care planning. Documents, whiteboards and computerized information can be shared. Hospitals interconnect through networks usable over the Internet and health-care services can be linked to remote clinical centers that will an provide them with specialized assistance. Systems are relatively easy to set up and DICOM, the standard in medical imaging systems, -digital imaging and communications in medicine- [2], has provided a framework for such data exchange. Furthermore, videoconferencing allows people at remote sites to interact via two-way video and simultaneous audio transmissions. Seeing people face to face can be especially useful for diagnosis, consulting, with the added bonus of commenting of transmission of medical images in real-time. Often sufficient, the store-and-forward, or otherwise called, asynchronous approach - when images or bio-signals are acquired from equipment and transmitted through a network later on - allows for off-line consultation/evaluation at remote health-care centers. Core technology for adequate audio/video streaming is compression (up to 1:500) while preserving quality of images, to allow for a proper diagnosis, is a challenge [3].

In most cases, collaborative evaluations of patients can be performed directly from peripheral health-care centers or outpatient physicians' offices, in connection with reference centers, using the store-and-forward approach. Diagnostic examinations can be shared between various clinical teams allowing for collaborative medical decision-making in diagnosis and patient care planning. When clinical conditions are critical or complex on the other hand, hospitals themselves may lack the needed experience and specialists may be called upon for help. Such cases may require real-time (i.e. synchronous) transmission capability in view to limiting risks and avoiding added morbidity and costs. Particularly with this solution, one must prepare for the occasional limited bandwidth and/or, instability or discontinuity of Internet connections. The store-and-forward solution for these instances, is good to have as back-up.

2. Methods

The main objective of this project was to allow collaborative diagnosis and care planning of congenital cardiac malformations. While echography studies, given the quality of instrumentation, allow to recognize abnormalities in neonates or in the foetus, the experience of operators is not often adequate in many hospitals. Thus it is frequently necessary to transfer urgently to specialized cardiac units newborns suffering critical cardiac disorders while early diagnosis and care planning would limit risks. Real-time interaction, via two-way video and audio transmissions, is useful in these cases for assisting the remote operator during echo scanning.

Tele-echocardiography was implemented (Figure 1) [4] using a couple of commercial videoconference devices, one installed at the echocardiography room in the remote hospital and the other one at the specialized unit, connected together through Internet. It was straightforward to plug the standard analog video output from echo-cardiographer in the videoconference equipment. Upload transfer rate greater than 512 kbps was needed for limiting degradation of diagnostic accuracy of echo images transmitted in real time from echo-cardiographer. Communication ports were properly set up to allow videoconferencing. However limiting factors of Internet related to stability and continuity of connections may affect the quality of diagnostic images. Store-and-forward is a useful alternative as correct off-line transmission of image records (DICOM or not) to remote center can be achieved over network (using TCP instead of UDP streaming protocol).

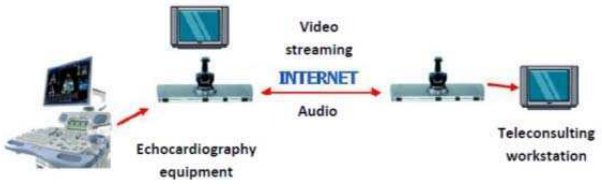

Figure 1. Tele-echocardiography by videoconferencing equipment.

2.1. Open-source tele-consulting

Videoconference commercial equipment are easily used, given their simple and friendly user-interface, but they are usually expensive, use proprietary technology and are limited in scalability and functionality. To face these limitations we applied Open-Source software and standard hardware to set up a low-cost device providing both on-line and off-line tele-consulting as well as videoconferencing (Figure 2) [5].

Basic requirements of this system are: video signal acquisition and digitization from imaging equipment; effective digital image compression; secure transmission of image data (DICOM and not) through public network; videoconferencing capability for on-line operator interaction; DICOM server utility for storage, management and distribution of image studies (PACS capability). Particular attention was dedicated to design a small-size device embedding all the required functions.

The web site *http://award.altervista.org* (Telemedicine Free Project) [6] was the main reference for software and hardware, we applied for implementing in our laboratory the prototype of the tele-consulting system.

LAMP architecture was adopted, consisting of:

- A Linux operating system (UBUNTU GNU/Linux distribution, http://www.ubuntu.com/).
- An Apache web server (http://tomcat.apache.org/).
- MySQL Community RDBMS database (http://www.mysql.com/ products/community/).
- PHP (general-purpose scripting language, suited for Web development, http://php.net/).

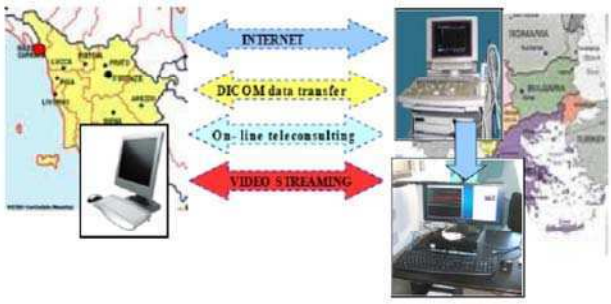

Figure 2. Tele-consulting: diagnostic images are transferred via Internet (on-line or off-line) from Balkan centers to the cardiac department in Massa for collaborative diagnosis of congenital heart malformations.

The following application software was applied:

- *Ekiga* (SoftPhone, Video Conferencing and Instant Messenger application over the Internet).
- *VLC* (cross-platform multimedia player and framework) (http:// www.videolan.org/vlc/).
- *Flowplayer* (embedding video streams into web pages, http://flowplayer.org/).
- *DCM4CHE* (Open Source Clinical Image and Object Management software, http://www.dcm4che.org/). It contains DICOM, HL7 services and interfaces to provide image storage and retrieval.
- *Oviyam* viewer (http://oviyam.raster.in/) (web-based DICOM viewer). Using standard DICOM protocols patient lists are queried, studies are retrieved and displayed in web browser.

Mini-ITX low-power motherboard was chosen to achieve small size tele-consulting workstation and Pinnacle DVC100 video card was used for digitizing video signal from the echo- cardiographer (Figure 3).

Graphical User Interface (GUI) and related functions were implemented by PHP and bash scripts (http://sourceforge.net/projects/teleconf).

At the diagnostic center the operator, using the tele-consulting workstation, can choose by local GUI among the following basic functions (Figure 3):

- LIVE: for transferring by streaming in real time the video signal acquired from analog output of echo-cardiographer.
- DICOM: for managing and distributing image studies achieved by DICOM sources (echo-cardiographer or other modality diagnostic equipment).

- ARCHIVE: for recording (by acquisition and digitization) video signal from echo-cardiographer into standard file.

At the receiving side (e.g. at the cardiac department in Massa) by means of a standard web browser, connecting to the public Internet address of the remote workstation, diagnostic images are reproduced on computer monitor, invoking video streaming (LIVE or ARCHIVE) or retrieving DICOM records by Ovijam.

Real-time video streaming requires a minimum value of the upload Internet bandwidth (512 Kbps) to avoid loss of diagnostic information.

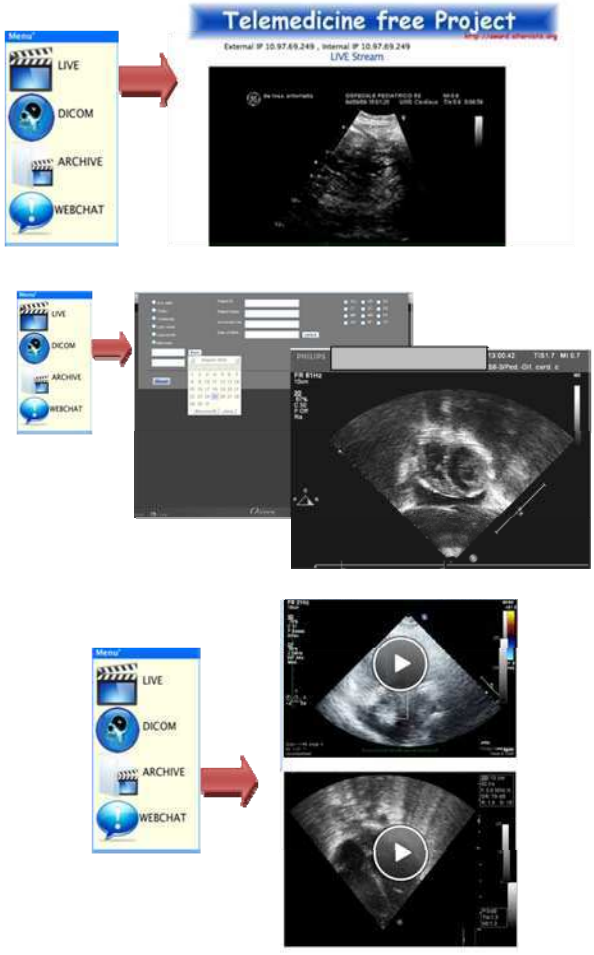

Figure 3. Different functions at receiving browser (top do down: LIVE, DICOM, ARCHIVE).

3. Tele-consulting network

The main objective of the project developed by the G. Monasterio Foundation with the financial support of both "Un Cuore un Mondo" (Heart-World) Association and the Tuscany Region in Italy was to cooperate with clinical centers of Western Balkan Countries (Croatia, Bosnia & Herzegovina, Albania, Kosovo, Montenegro) in the diagnosis and care of congenital heart malformations. In addition to neonate or infant patients great attention is dedicated to the fetus in order to allow early detection and planning [3-5] of care, treatment and/or intervention (even delivery close to surgical center) avoiding risks and limiting costs. Hence training of health care personnel, involved in diagnostic examinations, is an important task of the cooperation project. First achievement of the project was the development of a network for tele-consulting, interconnecting by Internet clinical centers of Balkan Countries with the cardiac department of Heart Hospital in Massa, actually a reference center in diagnosis and care of congenital heart diseases.

Initially, tele-echocardiography was implemented at Pediatric Clinical Centers of both Banja Luka (Bosnia and Herzegovina, BIH) and Rijeka (Croatia), and later at Gynaecology Hospital in Tirana (Albania). Further workstations have been recently delivered and installed at other BIH clinical centers (Tuzla, Sarajevo and Mostar) where regular service will start as soon as upload Internet requirements will be fully provided.

Commercial videoconference equipment (Aethra Vega X3 or X5) were applied for transmitting over Internet sequences of echocardiographic images. Network infrastructure at hospitals was properly set up to allow use over Internet of videoconference communication protocols. Upload Internet connection bandwidth greater than 512 Kbps was required to limit degradation of diagnostic quality of images across network.

Using multi-conference utility (MCU) it was possible to meet together on-line teams at more clinical centers to allow discussions of common interest or collaborative clinical evaluations.

During tele-consulting sessions, usually requested by remote centers, young patients (often neonates) suffering by cardiac disease were studied during echocardiography examination jointly by physicians at remote site and cardiologists at Heart Hospital in Massa. Fetal echocardiography was also performed for allowing early care planning before delivery.

Live tele-consulting is crucial in case of critical cardiac conditions in order to plan timely care or intervention of patients and also to interact with the remote echocardiography operator for proper scanning of heart anatomy, especially in the fetus or neonate. Sometimes limitations of public network bandwidth (Internet), unstable in time, affect quality of diagnostic images and degradation is too high making it difficult detection of cardiac abnormalities also by expert cardiologists. In these situations store-and-forward tele-consulting is suggested to transfer imaging records preserving full diagnostic information.

The prototype of tele-consulting device, embedding Open-Source software components according to section 2.1, was set up at our institute, allowing both on-line

streaming of video signals for real-time interaction and off-line transmission of diagnostic images (DICOM and not) in addition to videoconferencing and image storage and management. It was first successfully tested within the hospital and next in Mostar (Bosnia-Herzegovina) in connection with Heart Hospital in Massa. Experimentation of this device is continuing, tuning software components and adapting user interface as much as needed to allow use in place of commercial equipment.

Figure 4. Tele-echocardiography from Pediatric Center in Banja Luka (BIH).

4. Conclusions

While commercial videoconference equipment allowed easy implementation of tele-echocardiography in clinical centers of Balkan Countries for diagnosis and care planning of congenital heart diseases, this solution is limited in terms of functionality, versatility, scalability and cost/effectiveness.

Low-cost Open-Source systems, enabling both image management and transmission over Internet, are challenging for the diffusion of tele-consulting for collaborative medical decision making, not only in congenital heart diseases but potentially in the diagnosis of any medical pathologies (liver, kidney, ...), providing specialized care virtually anywhere through Internet. The device, set up at our laboratory, overcame preliminary tests and soon will be evaluated. Both on-line and off-line tele-consulting functions were implemented, in addition to image archiving capability, using low-size hardware. Further improvements will concern the user interface and adoption of image compression methods for preserving diagnostic accuracy of images with maximal reduction of bandwidth.

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