

Open-source Teleconsulting System for International Cooperative Medical Decision Making in Congenital Heart Diseases

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Abstract

A project was developed by Heart Hospital in Massa, supported by Cuore un Mondo Association and Tuscany Region, for medical cooperation with Balkan Countries in diagnosis and care of congenital heart diseases. First step was to set up a telemedicine network aimed at multi-center cooperative medical decision making. Tele-echocardiography was initially implemented at pediatric clinical centres of Banja Luka, Rijeka and Tirana, using videoconference equipment for transmitting over Internet sequences of medical images. Actually videoconference systems are expensive, use proprietary technology and have limited functions. To overcome these limitations we designed a low-cost Open-Source-based device 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 videoconference and image storage/management functions. This device is also challenging for use also in remote Countries not able to acquire expensive medical technology.

1. Introduction

Major advances in information and communication technology have provided a solid foundation for telemedicine applications (tele-diagnosis, tele-consulting, tele-conference) breaking down geographical barriers and providing specialized medical care virtually anywhere in the world. On the other hand adoption of DICOM standard in medical imaging systems has allowed multi-center data exchange. One of telemedicine applications that is increasingly used is tele-consulting, based on transmission of medical images over network, aimed at multi-center cooperative medical decision making in diagnosis and care planning. Actually this is still limited by a number of reasons. First, imaging studies produce a huge amount of data. Data storage and transmission through public networks need to apply

compression techniques, effective for data reduction but preserving the quality of diagnosis based on received images. Powerful compression algorithms (either lossless or lossy) are reported in DICOM standard but a comprehensive evaluation of diagnostic accuracy is lacking, because it is a function of quantitative parameters but it depends on subjective clinical decision related to complex knowledge models. According to store-and-forward approach, DICOM images, ready at the end of the single study, can be transmitted through network (encrypted for data security), allowing off-line tele-consulting at remote health-care centres. On the other hand real-time transmission capability is crucial when specialists should assist remotely the operator driving proper scanning during imaging examination. That is the case of echographic study on patient or fetus with suspected congenital abnormalities. Internet, the worldwide public network, allows low-cost implementation of telemedicine applications while limiting factors related to stability and continuity of connections need to be considered. Videoconference equipment, commercially available, can be used to transmit over public network (Internet) video signals provided by imaging equipment. Tele-echocardiography was launched, in collaboration



Figure 1. Telemedicine network in Balkan area

with “Cuore un Mondo” Association, using such equipment to relay information between Pasquinucci Heart Hospital of Monasterio Foundation in Massa and remote centers in Balkan Area, by Internet connection with upload transfer rate of 512 kb/s. Actually commercial solutions are expensive and use proprietary technology limiting their applications in clinical practice. Diffusion of telemedicine applications would be effectively promoted providing health-care institutions with low-cost systems, based as much as possible on Open-Source technology, specifically developed according to clinical requirements.

Initial scope of this project will be the tele-diagnosis of congenital cardiac abnormalities. While echography studies, given the quality of high-tech instrumentation, currently available in many clinical centers, allow to recognize abnormalities even in the fetus, less than 20% of diseases are detected in prenatal period because these examinations require specific training and experience, often not adequate in many hospitals. Thus it is frequently necessary to transfer urgently to specialized cardiac units newborns suffering by critical cardiac disorders while early care planning, before delivery, would limit risks avoiding consequences in term of morbidity, costs and legal implications.

2. Methods

Today most systems for diagnostic imaging modalities (US, CR, CT, XA, MR) generate digital images in standard format (DICOM) which are commonly recorded and distributed by PACS. Complete studies can be conveniently transmitted in DICOM format to remote sites by Internet using proper compression techniques and adopting security measures. This approach (store-and-forward) becomes inadequate when real-time interaction is needed such as in the case of assisting the remote operator during echo scanning for diagnosis of congenital malformations in the neonate or in the fetus. For achieving real-time tele-consulting analog video signal is acquired directly from imaging equipment, digitized, compressed and transmitted over network.



Figure 2. Use of teleconference equipment in tele-echocardiography

Videoconference equipment, commercially available, are useful to transmit on-line over any network video signals provided by imaging equipment. Tele-

echocardiography was first implemented (Figure 2) using such equipment assuring Internet connections with upload transfer rate greater than 512 kbps for limiting degradation of diagnostic accuracy of images. However limiting factors of Internet related to stability and continuity of connections affect the quality of diagnostic images. Store-and-forward is useful in case of low network performances by transmitting off-line image records (DICOM or not) to remote center for cooperative diagnosis.

2.1. Teleconsulting device development

Videoconference equipment are usually expensive, use proprietary technology and have limited functions. To face these limitations using available open-source software and common hardware a prototype of low-cost device for tele-consulting was developed. Both on-line and off-line tele-consulting in addition to videoconference and image storage/management functions were implemented (Figure 3). Basic functions of this system are: DICOM server for storage and management of image studies; digital image compression by effective algorithms; video signal acquisition from imaging equipment for on-line tele-consulting; secure transmission of image data (DICOM and not) through public network; teleconference capability for on-line operator interaction. Particular effort was dedicated to design small-size equipment.

Basic architecture consists of LAMP frame-work (Linux operating system/Apache web server/MySQL RDBMS database/PHP scripting language), Ekiga (for operator interaction, by H323 and SIP), VLC (media player supporting common audio/video codecs and protocols for streaming over network), DCM4CHE (for storage and distribution of DICOM image studies).

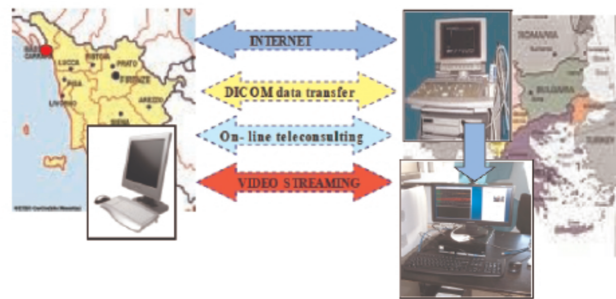


Figure 3. Structure of the teleconsulting system.

3. Results

Initially tele-echocardiography was implemented at Pediatric Clinical Centres of both Banja Luka (Bosnia and Herzegovina) and Rijeka (Croatia), and later at Gynaecology Hospital in Tirana (Albania). Further

workstations will be installed within October 2010 in the clinical centres of Tuzla, Sarajevo and Mostar (BIH).

Commercial videoconference devices (Aethra X3 or X5) was applied for transmitting over Internet sequences of echocardiographic images. Video output signal of echo equipment was connected with videoconference device. Network at hospitals was properly set up to allow use of videoconference transmission protocols. Upload Internet connection bandwidth greater than 512 Kbps was required to limit degradation of diagnostic quality of images across network.

During tele-consulting sessions, usually requested by remote centres, 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.

On-line tele-consulting is crucial in case of critical cardiac conditions in order to plan timely care or intervention of patients. Sometimes limitations of public network bandwidth (Internet), not stable in time even if guaranteed by local providers, affect quality of diagnostic images and degradation is too high making it difficult detection of cardiac abnormalities also by expert cardiologists. Store-and-forward is useful in such cases to complete diagnostic examinations.

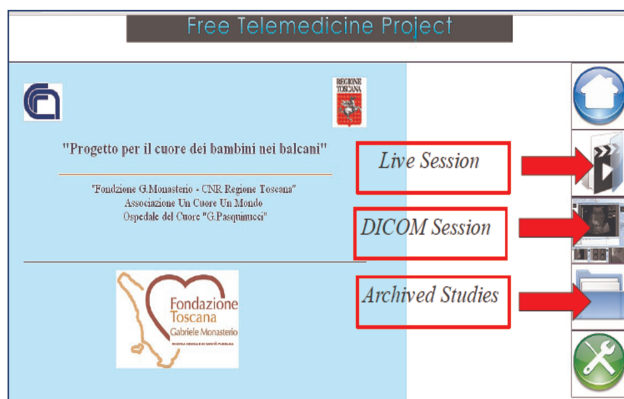


Figure 4. User interface of teleconsulting device

To cope with these problems a special device, extending functions of videoconference equipment with image storage and distribution, DICOM or not, was designed in our laboratory. Open Source technologies, following guidelines published also on web (<http://award.altavista.org>), were adopted to limit costs for promoting the diffusion of tele-consulting. The developed system allows both real time and off-line tele-consulting while basic PACS capability is provided.

Mini-ITX low-power motherboard was chosen to achieve small size equipment. As described in methods,

the system architecture is based on LAMP frame-work and Ekiga (H323 and SIP compliant) was applied for on-line operator interaction. VLC free media player was used for streaming over network. DCM4CHE (Open Source Clinical Image and Object Management software) was implemented for storage and distribution of DICOM image studies provided by imaging equipment; Oviyam was applied to review imaging records by standard web browser. Flash Video was applied to deliver not-DICOM images over Internet, using buffering for limiting loss of information.

The prototype was set up and has been tested in our laboratory; it will be evaluated on the field during the next mission in Bosnia in connection with Pediatric Department of Heart Hospital in Massa.

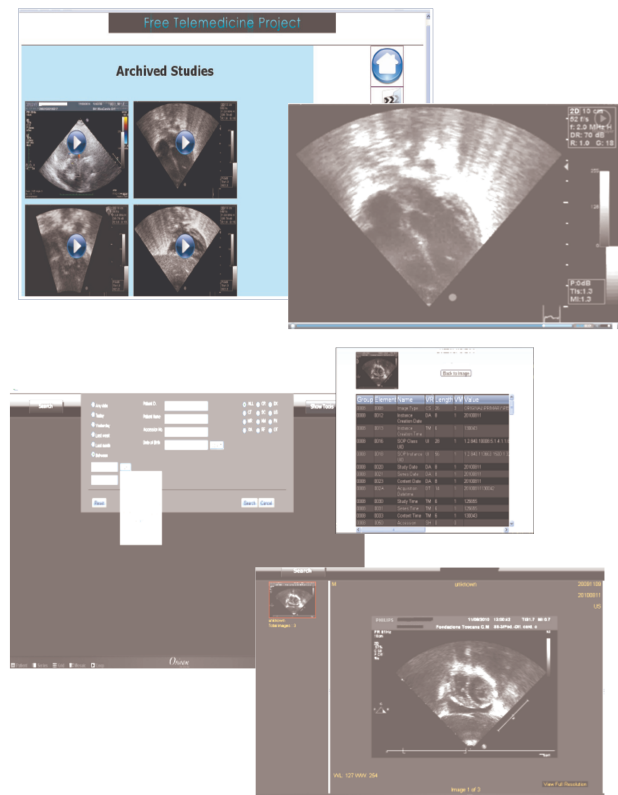


Figure 5. Off-line teleconsulting: examples of not-DICOM (by Flash) and DICOM records (by Oviyam) (from top to bottom).

4. Conclusions

While commercial videoconference equipment allowed us to implement tele-echocardiography in Balkan Countries for diagnosis and care planning of congenital heart diseases, this solution is limited in terms of functionality, scalability and cost.

Low-cost Open-Source systems, enabling both image management and transmission over public network (Internet), are challenging for the diffusion of teleconsulting for cooperative medical decision making not only in congenital heart diseases but potentially in the diagnosis of other medical pathologies (liver, kidney, ...),



Figure 6. Tele-echocardiography on neonate from Banja Luka

providing specialized medical care virtually anywhere in the world. The device, set up at our laboratory, overcame preliminary tests and soon will be evaluated on the field. Both on-line and off-line teleconsulting 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.



Figure 7. Fetal tele-echocardiography from Tirana

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