Telemedicine Network for Early Diagnosis and Care of Heart Malformations

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Abstract— **Health cooperation with Balkan Countries in pediatric cardiology and cardiac surgery was the objective of the joint project involving the staff of pediatric division at G.Pasquinucci Heart Hospital in Massa (G.Monasterio Tuscany Foundation) and the voluntary Association "Un cuore un mondo". Since 2008 the Tuscany Region supported this initiative, which was aimed at collaborative diagnosis and care of congenital heart malformations. A multi-center telemedicine network was developed interconnecting through Internet the Heart Hospital in Massa with selected pediatric and gynecology centers of Croatia, Bosnia-Herzegovina, Albania and Romania. Tele-echocardiography was implemented for transmitting on-line diagnostic images. Patients with critical defects, assisted by volunteers of "Un Cuore un Mondo" association, were transferred to Massa for adequate care and/or intervention as well as before delivery in case of fetus malformations. The achievements of the Balkan experience have promoted the development of a new project in the Tuscany region to provide neonatology/prenatal units with tele-consultation service in congenital heart malformations. On the technical side, videoconferencing technologies were applied for tele-echocardiography and Open-Source solutions were experimented to set up low-cost devices implementing both live and store-and-forward tele-consulting.**

Keywords— **Telemedicine, Congenital Heart Malformations, Tele-echocardiography, Second opinion diagnosis, Health-care cooperation.**

I. INTRODUCTION

Diagnosis and care of congenital heart malformations is usually referred to specialized pediatric centers. Given the wide-bandwidth networks, interconnecting today main health institutions, it is conceivable to set up low-cost telemedicine services, from reference to secondary health-care centers, providing collaborative diagnosis, care and follow-up of congenital heart malformations, in the fetus, in the newborn or child up to adult patient. Many telemedicine experiences are reported throughout the world [1] and regular services are provided in various fields. DICOM, the standard in medical imaging systems, provided a framework for easy image exchange [2]. Often sufficient, the store-and-forward, or asynchronous approach, allows for off-line consultation by use of secure network connections. Core technology for audio/video streaming is compression but reaching desirable data reduction, while preserving sufficient quality to allow a diagnosis, is a challenge. Need for limiting data flows over networks and time constraints in case of real-time transmission require to adopt loss powerful compression [3]. Nevertheless, true diagnostic quality is dependent on complex human knowledge models and compressed images are usually adequate, as reported in many studies, for allowing second opinion diagnosis.

Pediatric tele-echocardiography has been used over many years in various countries, since the earliest experience in clinical cardiology in 1989 [4] to first live transmission of neonatal echocardiograms in 1996 [5]. Sable et al. in 2002 [6] evaluated the impact of telemedicine on delivery of pediatric cardiac care in community hospitals, reporting use of desktop videoconferencing computers over ISDN (Integrated Services Digital Network) lines. Later, a number of studies were reported on remote diagnosis of congenital heart disease: while echography equipment allows recognizing subtle cardiac abnormalities, in the neonate or even in the fetus, but the skill of local sonographers is often not adequate, live guidance during patient examination is demanded in order to reach an expert-enlightened joint echocardiography diagnosis. High diagnostic accuracy was achieved transmitting both neonatal and fetal echocardiograms with live guidance by pediatric cardiologists [7-9]. Impact of telemedicine on shortening the time to diagnosis, preventing unnecessary patient transports and reducing length of hospitalization was recently reported [10].

Taking into account the previous experiences, the synchronous approach was applied in our project for implementing tele-echocardiography across the public network (Internet), having the store-and-forward solution as backup in case of discontinuity of network connections. Commercial off-the-shelf technologies for videoconferencing were initially applied [11] while Open Source systems have been experimented as low-cost alternative solution.

I. Lacković et al. (eds.), *The International Conference on Health Informatics*, IFMBE Proceedings 42,
DOI: 10.1007/978-3-319-03005-0_68,

II. TELE-ECHOCARDIOGRAPHY BALKAN NETWORK

Our project was developed at the "G. Pasquinucci" Heart Hospital of "G. Monasterio" CNR/Tuscany Foundation (FTGM) in Massa, tertiary center for pediatric and adult cardiac surgery, jointly with the volunteers of "Un Cuore un Mondo" Association and the support of International Health-Care Cooperation program of Tuscany Region in Italy. The goal was to set up a cooperative network with the clinical centers in Balkan Countries for supporting the diagnosis and care of congenital heart malformations.

Initially (2008) the Pediatric Clinical Centers in Banja Luka (Bosnia & Herzegovina) and in Rijeka (Croatia) were contacted and enrolled in the network project [12]. Next (2009), "Koco Gliozheni" Gynecology University Hospital in Tirana (Albania) joined. Later other centers in Bosnia & Herzegovina (Gynecology Hospital / Sarajevo, Pediatric Hospitals / Tuzla and Mostar) as well as in Romania (Bucharest) were involved [13-14].

Fig. 1: The telemedicine network for heart malformations.

A telemedicine network connecting the remote clinical sites in the Balkan Area with the cardiac department of the Heart Hospital in Massa/Italy (the reference center) was set up over the Internet (Fig.1).

Videoconferencing equipment (Aethra Vega X3/X5) was applied, according to previous experiences [6-9,11], for implementing real-time tele-echocardiography. Standard audio/video interaction was provided between the pediatric cardiologists in Massa and the sonographers/physicians at the remote Balkan sites. Echocardiograms were performed on existing machines by use of image windows according to the suggestions of the guiding pediatric cardiologists. The video analogue output (typically S-video) of the echocardiography machine was connected with the videoconferencing equipment which is provided with COder/DECoder hardware for image acquisition/digitization and efficient data compression allowing transmission in real-time by standard H.323 protocol on IP network [3]. Upload data transfer rate, greater than 512 Kbps, was provided to ensure quality and low latency of transmitted echocardiographic images. At the Heart Hospital in Massa the echocardiographic images were decompressed and displayed for teleconsulting (Fig.2).

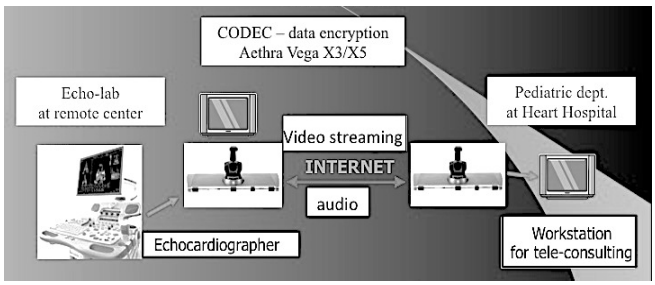

Fig. 2: Tele-echocardiography using videoconferencing equipment.

Real-time tele-echocardiography was implemented at both pediatric (Fig.3) and gynecology (Fig.4) centers.

During the tele-consultation the young patient or the fetus, with suspected cardiac abnormality, was studied by echocardiography jointly by physicians at the given remote site and at the Heart Hospital in Massa. Real-time tele-consultation, allowing interaction with the sonographer at remote site for proper scanning of heart anatomy [6], helped to plan timely care or intervention in case of critical or complex conditions, even transferring pregnant women before delivery in case of fetal abnormalities.

Standard cryptography was applied for data protection. At times, limitations of public network bandwidth (the Internet), or instability of it, affected quality of diagnostic images and the degradation was high enough to render detection of cardiac abnormalities difficult. In these situations store-and-forward solution was applied as alternative, transferring imaging records (possibly in DICOM format) thus preserving diagnostic information.

Fig. 3: Tele-echocardiography on a neonate from Banja Luka.

Fig. 4: Fetal tele-echocardiography from Tirana and Sarajevo.

Average costs for videoconferencing instrumentation at each site were around 4000 €, excluding costs for connectivity, usually accounted as general hospital expenses. Expenses for transferring patients to Massa and for caring them were jointly supported by Cooperation program of Tuscany Region and by "Un Cuore un Mondo" Association.

A. Results

Three centers (Banja Luka, Reijka and Tirana) have been using the telemedicine network in the last four years while the others, although videoconferencing facilities were installed from time, didn't start. Tele-consultation service was provided on demand by pediatric cardiologists, helped by technicians, in Massa, usually within one day or earlier as possible in case of urgency. In the last years, after the tele-consultation service was made available, a total of 82 patients (29 neonates, 30 infants and 23 children) were transferred from Albania, Bosnia and Croatia for cardiac surgery intervention (Table 1). Each patient or fetus was first examined by tele-echocardiography in most of the cases. While a part of them were evaluated not complex, minor or normal, the others were transported to Massa for cardiac surgery intervention or care. Even pregnant women, in case of critical fetal abnormalities, were transferred before delivery to the birth center in Massa to allow prompt intervention on newborns for limiting risks. Follow-up of patients, going back to home, was facilitated by use of the network.

Videoconference meetings and workshops were organized for discussion of clinical cases and for training healthcare personnel. Nevertheless, adequate exploitation of the network requires refining the cooperation agreements with the hospitals which were not really active, thus promoting wide cooperation in health care in the Balkan area.

III. A TELEMEDICINE NETWORK IN TUSCANY REGION

A new telemedicine network is currently developed in Tuscany, using the regional Wide Area Network (WAN-RTRT) interconnecting the FTGM Heart Hospital in Massa with the neonatology and prenatal centers across the region. The aim is to provide regular services for collaborative diagnosis and care planning of congenital heart malformations. Using videoconferencing instrumentation, real-time tele-echocardiography is implemented, as experienced in the cooperation project with Balkan countries. Store and forward utility is provided to handle network discontinuity. Telemedicine services for elective cases are regularly scheduled weekly, involving pediatric cardiac specialists, assisted by nurses and computer technicians, while 24h emergency service will be organized for urgent cases.

Table 1: Patients transferred to Heart Hospital for cardiac surgery.

DIAGNOSIS	***Albania***	***Bosnia Herzeg.***	***Croatia***
Aortic valve disease	3		1
Atrial septal defect	1		
Atrioventricular septal defect	6		7
Coarctation of aorta	1		3
Conduit failure			1
DOLV	1		
DORV	3	1	
Hypoplastic left heart syndrome			3
Mitral valve disease		1	1
Patent ductus arteriosus	3		3
Pulmonary atresia	2	2	1
Pulmonary stenosis	3		
Single ventricle	2	1	3
Tetralogy	2		1
Total anomalous pulm. venous	1		4
Transposition of great arteries	6	2	5
Tricuspid valve disease - Ebstein's			2
Truncus arteriosus	1		2
TOTAL of patients	**37**	**7**	**38**

IV. THE OPEN-SOURCE CHALLENGE

Videoconferencing commercial equipment are easily used but they use proprietary technology and are limited in scalability and functionality. Open-Source (OS) technology was exploited to set up a low-cost device enabling both on-line and off-line tele-consultation in addition to videoconferencing. A prototype was designed, using low-power computer hardware under Linux operating system (www.ubuntu.com) and equipped with standard video card (Pinnacle DVC100) for image acquisition from echocardiography machine [13]. OS software was applied to: digital image compression and streaming (www.videolan.org/vlc/);

videoconferencing (ekiga.org/); DICOM image storage/management (www.dcm4che.org/) and web view (oviyam.raster.in/). At remote secondary site the operator (sonographer or physician) real-time transmission of medical imaging study and store and forward utility (DICOM or not). At the receiving site medical images are displayed through web-browser. The prototype was first experimented from Mostar to Massa [14]. On-going development should lead to an alternative low-cost solution to commercial ones.

V. CONCLUSIONS

Telemedicine, breaking down geographical barriers, is allowing the delivery of specialized medical care virtually anywhere. Real-time tele-echocardiography allows collaborative medical decision making in diagnosis and care planning of complex and critical defects such as heart malformations [6-9,11-12]. It plays an important role in the early diagnosis or exclusion of pediatric cardiovascular diseases in patients admitted to remote secondary hospitals. Continuous medical training for the staff at those hospitals is achieved promoting the improvement of quality of care and the continuity of care, limiting patient mobility to cases of complexity or urgency. Overall cost reduction for care of heart malformations is expected [10] saving examinations, hospitalizations and unnecessary patient transfers.

Many projects often fail to grow beyond the pilot phase of technical implementation, because other than the usual barriers, namely, reimbursement and legislation, user acceptance of telemedicine technologies is essential [15].

Open-Source technology, embedding existing hardware or off-the-shelf devices [11], is challenging for promoting diffusion of telemedicine networks, potentially in any medical field and worldwide across the public network.

ACKNOWLEDGMENT

We thank for collaborative efforts the clinical and technical teams of Balkan centers participating to this project, particularly Prof. V. Ahe (University of Rijeka - School Medicine), Dr. R. Moisiu ("Koco Gliozheni" Gynecology Univ.Hospital - Tirana), Dr. S. Bajic and Dr. D. Djukic (Pediatric Clinical Centre, Banja Luka). Thanks to "Un Cuore un Mondo" Association and their president Mr. M. Locatelli, for financial support jointly with Tuscany Region.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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