Chapter

Telemedicine Network in Pediatric Cardiology: The Case of Tuscany Region in Italy

Alessandro Taddei, Pierluigi Festa, Fabrizio Conforti, Giuseppe Santoro, Gianluca Rocchi and Luciano Ciucci

Abstract

Four years ago, a telemedicine project in diagnosis and care of congenital cardiac malformations was developed in Tuscany interconnecting the Heart Hospital of Gabriele Monasterio Tuscany Foundation (FTGM) in Massa with main clinical centers around the region. Both live and store-and-forward tele-echocardiography were implemented, while the FTGM medical record system was applied for collaborative reporting. Mobile medical-grade carts, equipped with videoconferencing and computer units, were installed at main neonatology/pediatric centers throughout the Tuscany region. Today, 13 hospitals are connected to the network, while the MEYER Pediatric University Hospital (MEYER) in Firenze has recently adhered to the project, as HUB center jointly with FTGM, so enabling H24 telemedicine service in pediatric cardiology throughout the region. So far, more than 200 patients were diagnosed and followed by telemedicine.

Keywords: telemedicine, tele-echocardiography, pediatric cardiology, congenital heart diseases

1. Introduction

In the last decades, the birth prevalence of congenital heart diseases progressively increased to a maximum of 9/1000 worldwide [1]. Echocardiography is the most commonly used noninvasive cardiovascular imaging modality and is considered to be both safe and cost-effective, but often expert evaluation of heart malformations is not usually available in community hospitals. Advancements in technology and broadband have allowed to set up effective tele-echocardiography services, now routinely used for transmitting cardiovascular ultrasound images to remote consultation centers for expert analysis and interpretation [2]. Thus, prompt accurate decision-making involving therapeutic or intervention planning is enabled, early in the fetus before delivery, in the newborn, or in the child up to adult patient.

The Gabriele Monasterio Tuscany Foundation (FTGM) (www.ftgm.it) is a healthcare institution of the public regional system, specialized in multidisciplinary research, diagnosis, and care of cardiovascular diseases, including interventional cardiology and cardiac surgery in both adult and pediatric patients. The FTGM Heart Hospital in Massa is currently a regional reference center for surgical and

interventional treatment in neonatal and pediatric patients, as well as for fetal diagnosis of heart malformations. At FTGM the medical informatics staff has long time expertise in clinical information technology.

Ten years ago, the Pediatric Cardiology and Cardiac Surgery teams of the FTGM Heart Hospital in Massa, supported by the medical informatics researchers jointly with the volunteers of "Un Cuore un Mondo" Association, were involved in the International Healthcare Cooperation program of Tuscany region. The goal was to set up a cooperative network with the clinical centers in the Balkan countries, from Croatia to Bosnia-Herzegovina, Albania, and Romania, for supporting by telemedicine the diagnosis and care of congenital heart malformations.

Tele-echocardiography system was first implemented by the FTGM medical informatics staff at Pediatric Clinical Centers of Banja Luka (BIH) and Rijeka (KR), at the Gynecology Hospital in Tirana (AL). Later, other centers in Bosnia-Herzegovina (Gynecology Hospital in Sarajevo and Pediatric Hospitals in Tuzla and Mostar) as well as in Romania (Bucharest) were involved [3, 4]. Newborn and young patients with suspected heart malformations were evaluated on demand by tele-echocardiography from pediatric cardiologists at the HUB in Massa assessing the abnormal or critical cases. Up to 100 were transferred from Albania, Bosnia-Herzegovina, and Croatia for cardiac surgery. Each patient or fetus was first examined by tele-echocardiography in most of the cases. 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 the use of the telemedicine network.

Later, jointly with the National Research Council (CNR) Institute of Clinical Physiology (CNR-IFC), the FTGM participated to the European IPA Program in the project AdriHealthMob aimed at developing a cross-border model of services for healthcare in the Adriatic area. Fifteen partners of eight countries (Albania, Bosnia-Herzegovina, Croatia, Greece, Italy, Montenegro, Serbia, and Slovenia) were involved. AdriHealthMob platform for eHealth and eCare was designed for providing service through distance support for the rationalization of mobility up to the elimination of useless transfers for health and care [5, 6].

Four years ago, in Tuscany (a region in central Italy with 3 million of inhabitants, comprising a couple of major islands) the Lions Clubs achieved a grant (GA 14451/108-LA) from their International Foundation (LCIF) (www.lions.org) to support the FTGM for developing the regional telemedicine network in pediatric cardiology. This project (**Figure 1**) was launched in April 2015 with the aim of implementing pediatric tele-echocardiography for the diagnosis and care of cardiac malformations in neonatal and pediatric patients, as well as for follow-up of patients undergoing cardiac surgery. The main neonatology/pediatric hospital units throughout the Tuscany region were first interconnected with the pediatric cardiology department at FTGM Heart Hospital in Massa and later with MEYER Pediatric University Hospital (MEYER) in Firenze. Now, the FTGM and MEYER jointly serve as HUB reference center in the regional network, enabling H24 telemedicine service.

Tele-echocardiography is a process in which a provider or a technician obtains cardiovascular ultrasound images from a given patient, and these images are transmitted to an off-site location where a cardiologist can provide further analysis and interpretation. Thus, tele-echocardiography allows expert interpretation and consultation, promptly and without geographical limits, enabling accurate decision-making on triage, transport, and therapeutic or interventional plans [2].

Tele-echocardiography has been largely applied in pediatric cardiology over many years since the first live transmission of neonatal echocardiograms [7, 8]. The impact of telemedicine on delivery of pediatric cardiac care in community hospitals was assessed in many studies [9]. This approach was effective to increase

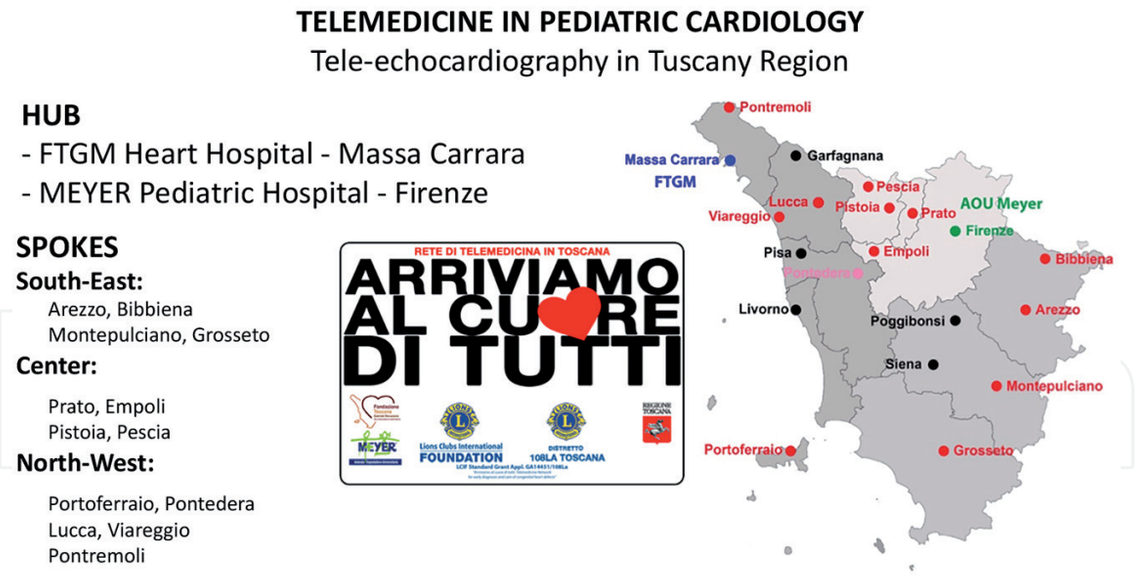

Figure 1.
Telemedicine network supported by lions clubs and their international foundation (LCIF) with the promotion of Tuscany region.

efficiency and quality of care, to improve echo examination quality, to prevent unnecessary transport of babies without critical heart disease, to enhance sonographer skill level, to yield financial savings, to decrease length of hospitalization, and to raise patient and physician satisfaction. More and more institutions are implementing tele-echocardiography [2, 10–18].

Basically, the physician ("operator"), observing the patient by echocardiography in community hospital, contacts the pediatric cardiologist at the reference center ("consultant") to obtain expert-enlightened joint diagnosis. In fact, while echography allows recognizing complex cardiac malformations, in neonate or even in fetus, often in community hospitals, the operator is not skilled to perform this analysis, and live guidance during patient examination is demanded to achieve actual diagnostic images. Thus, synchronous approach (online or live) in tele-echocardiography is preferred to the store-and-forward modality (recording echo-images and subsequently transmitting to the consultant).

2. Methods

HUB-and-SPOKE network was designed, interconnecting reference center of pediatric cardiology (HUB) with remote healthcare institution (SPOKE). Each SPOKE was securely connected to the HUB by encryption technology (VPN IPSec) through the institutional regional network (RTRT). Video communication technology was applied preferring hardware codec (coder-decoder) (H323 IP, download/upload >512 kbps) to software applications in order to enable friendly, effective, and reliable implementation, allowing to transmit echo-images in addition to videoconference signals [19]. The echo video signal is acquired from echography equipment, preferably through digital outputs (HDMI, DVI-D, display port), and transmitted by the codec to the consultant workstation. Standard compression (H264) is applied for allowing effective streaming and high diagnostic accuracy is assured in clinical practice, as reported in a number of studies [20, 21].

This solution was first applied for implementing tele-echocardiography in Balkan countries and later in the Tuscany region, where the FTGM and MEYER pediatric cardiology staff jointly served as HUB consultant center.

Live tele-echocardiography was implemented by the use of codecs at the two sides of the network (SPOKE and HUB), streaming echo-images over network from the echography room of community hospital to the consultant center during videoconference. Store-and-forward facility was provided to allow transmission of full-resolution DICOM images from echography equipment to HUB server for revision of live evaluation or off-line second-opinion evaluation. This option was also useful to overcome possible drawbacks in synchronous transmission of echo-images, mainly due to performance instability of public networks.

The use of medical information system (internally developed in the FTGM by informatics researchers) allowed the operator to document patient medical history and clinical conditions, to record echocardiography findings, to print out disclosure and informed consent, and to record diagnostic evaluation in agreement with the consultant pediatric cardiologist (**Figure 2**). Actually, the final report is signed by

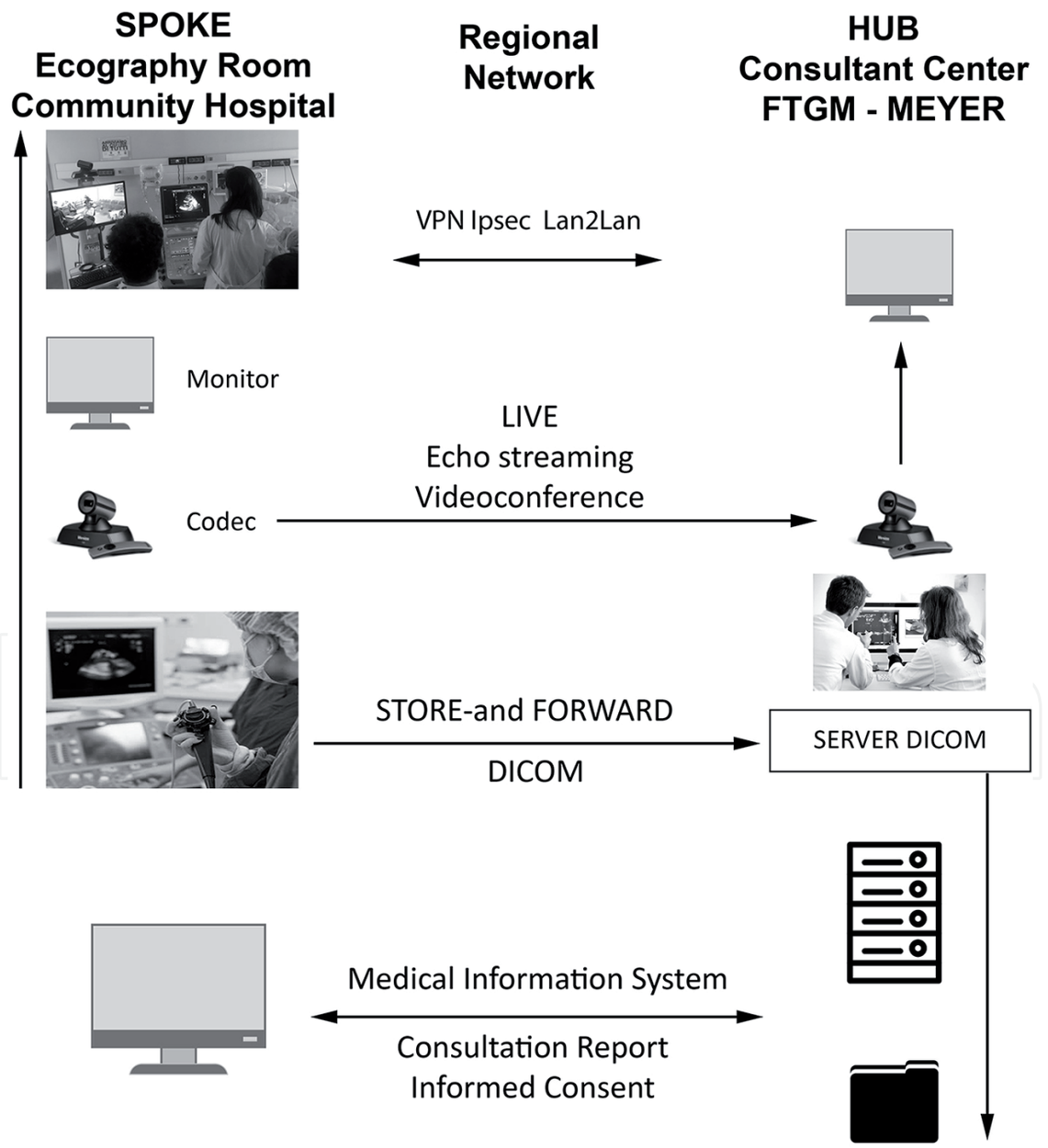

Figure 2.
Videoconference equipment was applied to implement live tele-echocardiography by secure connection of SPOKE setting with HUB center. DICOM images are transferred for revision and second opinion. Information system facilities are made available to manage diagnostic report and patient consent.

both the two physicians (the operator and the consultant) cooperating by telemedicine in patient diagnostic evaluation.

Tele-echocardiography session is a two-step process:

- First, live tele-echocardiography is achieved streaming echo-images during videoconference, so allowing the consultant to guide the operator for proper scanning of cardiac anatomy.

- Secondly, at the end of the patient echography examination, selected high-resolution DICOM images are transferred to the HUB center for allowing revision/confirmation of live diagnostic evaluations and definitive reporting.

Telemedicine guidelines, promoted in Italy by National Health System [22], were applied to set up regular and effective services for pediatric cardiology.

3. Regional telemedicine network in pediatric cardiology

Neonatology/pediatric units in Tuscany region are usually referred for diagnosis and care of cardiac malformations to two reference institutions: the FTGM Heart Hospital in Massa and the MEYER Pediatric University Hospital in Firenze.

Considering the great number (thousands each year) of outpatient visits at both FTGM and MEYER hospitals, telemedicine technology has a potential impact on healthcare throughout the region, facilitating expert evaluation and follow-up of so many patients. Families of young patients will benefit too, avoiding traveling with physical and emotional burden while saving money but also achieving early treatment for better patient care.

Following previous experiences in Balkan countries, FTGM developed the project "Arriviamo al Cuore di Tutti" to set up a pediatric tele-echocardiography network in Tuscany, aimed at interconnecting the reference centers (initially FTGM Heart Hospital in Massa and recently MEYER in Firenze) with main clinical centers throughout the region.

The Public Department of Health of the Region of Tuscany promoted the development of telemedicine network in pediatric cardiology, while the Lions Clubs of Tuscany (District 108LA), jointly with their International Foundation, contributed financial support to purchase all equipment for implementing teleconsultation service (**Figure 2**) [6].

According to telemedicine guidelines, promoted in Italy by the National Health System [22], the main goal was to allow accurate decision-making on the basis of the collaborative interaction between the echocardiography operator at each SPOKE and the expert pediatric cardiologist at the HUB (FTGM and MEYER).

Management and technical assistance are due to the FTGM technical staff and the technical organization of regional healthcare institutions (ESTAR).

Neonatology, cardiology, or pediatric care units of remote hospital (SPOKE) were provided with telemedicine workstations, able to transmit echocardiography images during the videoconference session, each one securely interconnected with the specialist center (HUB), serving teleconsultation or second-opinion requests. The HUB, facilities were provided for allowing multicenter videoconference, exchanging clinical data, and recording DICOM echocardiography images (**Figure 2**).

VPN communication infrastructure suitable for assuring, by standard IPSec protocol, security, and protection of health data, was set up over the existing regional large bandwidth infrastructure, interconnecting public institutions in Tuscany,

by the FTGM medical informatics staff in collaboration with their colleagues of the regional technical organization. The tele-echocardiography workstations were installed by FTGM staff at each SPOKE taking into account local needs or preferences of healthcare personnel.

Particular attention was dedicated to the training aspects for allowing effective at-distance collaboration in echocardiography evaluation of cardiac malformations. Initially, the training of SPOKE healthcare staff was planned at the Heart Hospital pediatric department or at their departments, while videoconferencing interaction during tele-echocardiography allowed the operator physicians to improve at distance more and more their skill throughout the project. Guides for management and troubleshooting of telemedicine service were provided by FTGM.

Consultation or second-opinion sessions were initially scheduled, involving pediatric cardiology staff at FTGM, with the assistance of computer technicians, while 24/7 regular service is being organized for management of emergency, urgent, and elective cases.

Live tele-echocardiography (as described in Methods) was implemented using videoconferencing equipment (codec), able to capture echo-images from ultrasound signal and to transmit them from the SPOKE over the network to the HUB by efficient standard compression (H264). So, the echo-images, examined by the operator at SPOKE center, are simultaneously replicated on the monitor at the HUB center (FTGM) where the pediatric cardiologist (the consultant), by videoconferencing interaction, is allowed to help the colleague achieving correct heart examination so cooperating to diagnostic evaluation.

The codec (Lifesize ICON 400), the monitor, and the video-camera were mounted on a mobile cart equipped with medical insulators on each external connection (ultrasound, network, and power lines) to allow movement and safe use in the hospital settings. The so-equipped system allows the consultant from the HUB to express a diagnostic opinion, so contributing to define one report, shared with the patient doctor at the SPOKE center. The telemedicine cart included a compact-type computer for medical reporting and optionally a printer (**Figures 3** and **4**).

Echography equipment was configured to allow (at the end of the examination) the transmission of selected heart images in DICOM format to the HUB server (store-and-forward option). These native resolution images allowed revision and confirmation of the "live" diagnostic evaluation. Moreover, this "off-line" modality will be useful for backup in case of connection failures or quality degradation during live session.

At each SPOKE center, a medical record application, developed and adapted by FTGM informatics staff, was made available [5]. Disclosure and informed consent (**Figure 5**) is recorded according to the privacy rules. Patient information is entered into the medical record (anamnesis, physical examination, diagnostic reports, conclusions); final report is achieved including signatures of both the operator and the consultant. New web-based release has been recently introduced to facilitate medical reporting.

Connection between the two HUB centers (FTGM and MEYER) also allows joint clinical discussion by videoconference, sharing all information on patients, particularly useful in the evaluation of complex and critical cases.

The physician at SPOKE center (operator) calls the HUB center (FTGM or MEYER) for activating videoconference connection and opens the medical record at the HUB to document patient history and physical examination. The informed consent is printed out and signed by the young patient's parents. The patient is identified on ultrasound equipment for allowing DICOM transmission at the end of the examination.

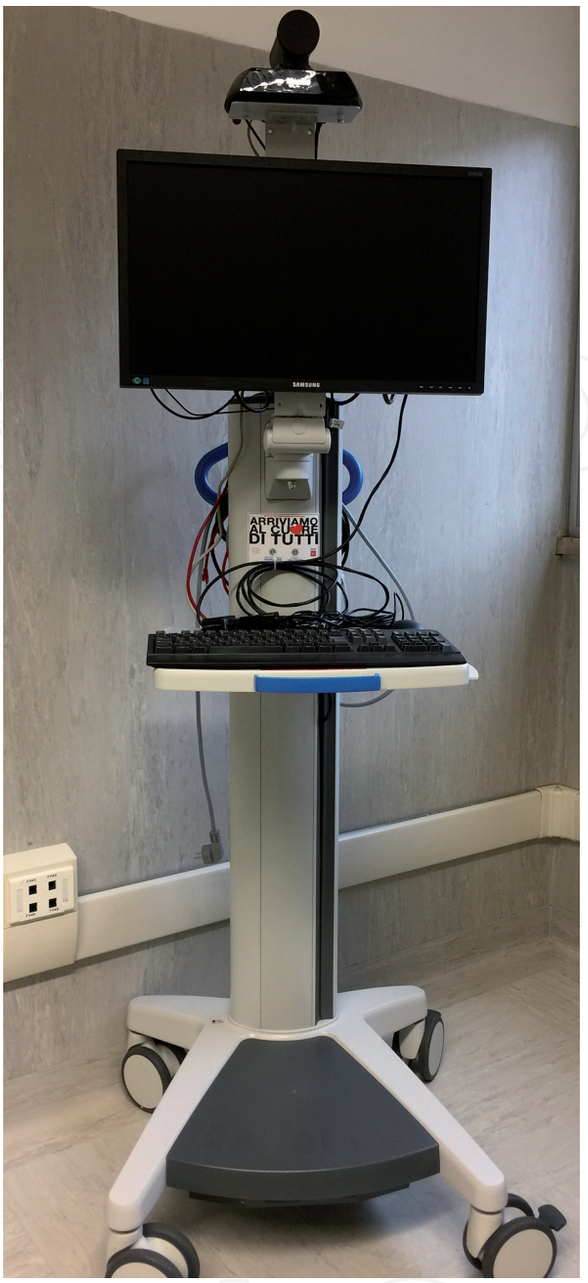

Figure 3.
Mobile medical-grade cart, equipped with videoconferencing and computer workstation, allowing use in clinical setting.

Figure 4.
Tele-echocardiography from neonatology (Prato and Viareggio).

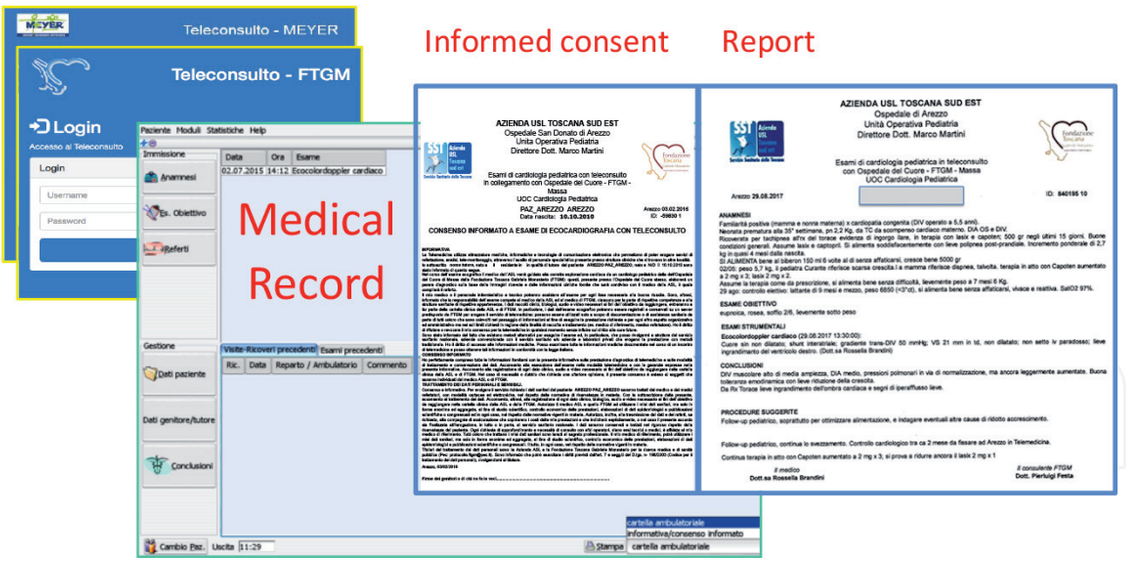

Figure 5.
The patient medical record, accessed by the user's password in the HUB/SPOKE network, is applied for documentation and for echocardiography reporting.

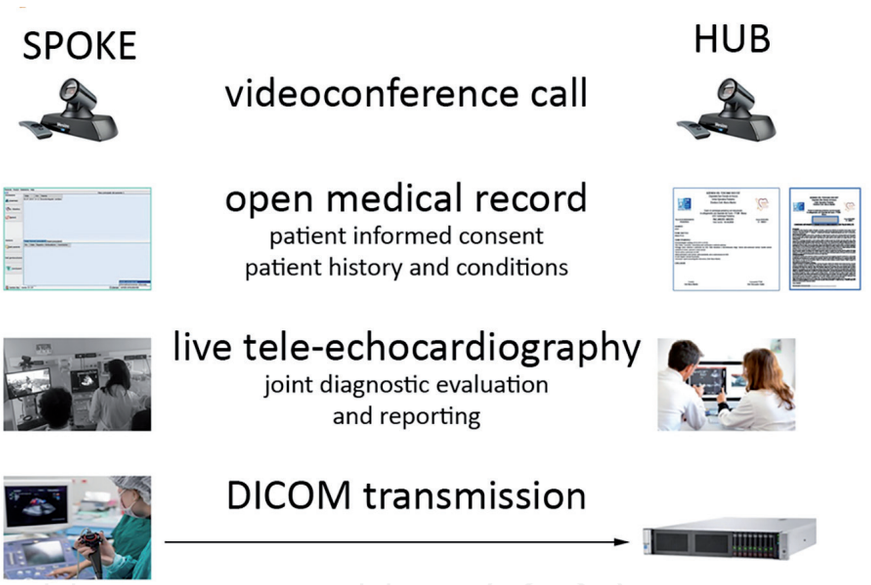

Figure 6.
Main steps of tele-echocardiography session.

Tele-echocardiography session starts with videoconference interaction between the operator and consultant: ultrasound images are "live" replicated at the HUB workstation for allowing cooperation of the consultant to diagnostic evaluation (**Figure 6**).

3.1 Research objectives

The aim of this project was to develop a telemedicine network for supporting medical decision-making in pediatric cardiology throughout the region, particularly in the diagnosis and care of heart malformations, usually referring to few specialized institutions. Large distances separate the patient and nonspecialist from expert advice.

Videoconference technology and medical information system solutions, previously internally developed in FTGM, were applied and implemented to set up a regional network, interconnecting HUB institutions (FTGM and MEYER Hospitals) with neonatology, pediatrics, cardiology, or gynecology (SPOKE)

centers. Each SPOKE center was equipped with tele-echocardiography workstation, allowing "live" consultation/second opinion in addition to face-to-face interaction for clinical discussion and care planning; medical record system was implemented for patient data exchange and reporting, and store-and-forward DICOM facility was provided for revision and documentation.

The main research objectives are summarized as follows:

- Set up low-cost/effective telemedicine network for supporting medical decision-making in pediatric cardiology.
- Allow collaborative medical decision-making for improving overall quality of care and promoting a real clinical network.
- Healthcare cost reduction avoiding unnecessary patient transfers or hospitalizations.

4. Results

Initially, the hospital of Elba island, in the south part of Tuscany, was involved as a pilot SPOKE center: secure network connection (VPN IPSec) was set up with the Heart Hospital in Massa (183 Km far away plus one hour for ship travel); the video output of the ultrasound equipment was connected to videoconference codec for streaming images to the HUB (**Figure 2**).

After the pilot action in Elba island, tele-echocardiography service was progressively deployed in all the provinces throughout the Tuscany region.

List of active SPOKE centers:

1. Elba island hospital (pediatrics)
2. Lucca (outpatient cardiology)
3. Empoli (outpatient cardiology)
4. Pontremoli (internal medicine)
5. Arezzo (ICU neonatology/pediatrics, outpatient cardiology)
6. Bibbiena (outpatient cardiology unit)
7. Prato (ICU neonatology and outpatient cardiology) (**Figure 4**)
8. Montepulciano (ICU neonatology/pediatrics, outpatient cardiology)
9. Viareggio (ICU neonatology/pediatrics department) (**Figure 4**)
10. Pistoia (pediatrics and cardiology)
11. Pescia (outpatient cardiology)
12. Pontedera (outpatient cardiology)
13. Grosseto (outpatient cardiology)

Another center was recently connected out of the region: Hospital of Cagliari (Sardinia region) (ICU neonatology/pediatrics).

According to the functional layout of **Figure 6**, "live" tele-echocardiography session is followed by "off-line" transmission of DICOM records to FTGM server for revision, while medical record system (running on FTGM server) is made available at the SPOKE center for documenting clinical conditions and for recording the report, agreed by both the physician operator at SPOKE and the specialist consultant at HUB. Information disclosure and informed consent are provided in agreement with legal constraints.

H24 tele-echocardiography service will be organized, jointly by the two HUB centers (FTGM and MEYER), to enable management of both urgent and elective cases.

SPOKE centers have started gradually their telemedicine activity: up to 200 patients (300 visits) were so far examined by tele-echocardiography.

The most active center resulted the pediatric department at Arezzo Hospital.

4.1 Telemedicine from Arezzo hospital

From April 2016 to May 2018, at the pediatric department of Arezzo Hospital, 65 live tele-echocardiography sessions in connection with the FTGM HUB have been performed in 26 children (from newborn until 6-year ones). Reports were produced by medical record system and DICOM images were also transmitted for revision and documentation. In 22 children (84.6%), telemedicine session was electively scheduled, whereas in 4 children, urgent remote specialized advice was required. The most frequent indication was heart murmur in 10, cyanosis in 9, and poor growth in 7 children. Only in one case, tele-echocardiography was inadequate for complete diagnosis. The most frequent diagnosis was the perimembranous ventricular defect (13/26, 50%), followed by atrial septum defect (2), partial pulmonary venous return (2), AV canal (2), hypoplastic aortic arch (1), pulmonary stenosis (1), and hypertrophic cardiomyopathy (1). Only in one case, echocardiography examination resulted completely normal.

Four telemedicine consultations were carried out in emergency: one patient was transferred for urgent surgical intervention (AV canal), two patients were electively operated after medical therapy bridge (hypertrophic cardiomyopathy and perimembranous ventricular septal defect), and the last one initiated optimal medical therapy for dilated cardiomyopathy. Twenty-two children were scheduled for elective follow-up: 1 after surgery and 21 before surgery. Seven outpatients underwent surgery: two for atrial septum defect OS, two for partial pulmonary venous return, three for perimembranous ventricular defect. Of the remaining 14 children, seven were followed up by telemedicine, and for the other ones normal follow-up was preferred. Therefore, unnecessary transfer to the regional HUB unit was avoided in 15 out of 26 patients.

5. Conclusions

Heart malformations in infants are very serious because they can affect the child's life if not cared from the very first hours after birth. The FTGM Heart Hospital is highly specialized in pediatric cardiac surgery, which annually saves many children coming from Italy and abroad, even from disadvantaged countries outside Europe.

In 2015 by the cooperation between the medical and technical professionals at FTGM, the telemedicine project in diagnosis and care of cardiac malformations ("Arriviamo al Cuore di Tutti") was launched with financial support provided from

both the Lions Clubs of Tuscany (district 108La) and the Lions Clubs International Foundation. The regional public health system approved this initiative promoting collaboration between healthcare institutions throughout the region.

Lions/LCIF budget enabled to purchase medical and computer equipment at the SPOKE hospitals in addition to server facilities at HUB center at both FTGM and MEYER.

Tele-echocardiography allowed collaborative medical decision-making in diagnosis and care of complex and critical heart defects. It played an important role in the early diagnosis, follow-up, or exclusion of cardiovascular abnormalities, planning patient mobility to tertiary specialist center when really necessary [23].

Now, 13 tele-echocardiography workstations have been installed in Tuscany and another one in Sardinia.

We expect that regional health authorities will continue to promote telemedicine service, dealing with reimbursement aspects and monitoring activity in the next years. Assistance and maintenance support will be likely organized in collaboration with the regional technical staff.

The main benefits of telemedicine network are summarized:

- Shortening the time to diagnosis limiting risks for patient
- Preventing unnecessary patient transports and avoiding discomforts for families
- Promoting a real clinical network, fostering collaboration between physicians and empowering the medical skill out of all centers
- Extending specialized remote consultation for follow-up of patients undergoing high-specialty interventions
- Improving quality of care in pediatric cardiology
- Reducing costs for both families and the public health system

As previously reported (Section 4.1) according to the experience at Arezzo Hospital, the effectiveness of the telemedicine network was assessed, while further developments are expected as more centers become really active. Transfers of newborns/children were avoided in many cases (58% in Arezzo) when could be good managed in place avoiding, consequently, unnecessary costs and patient/family discomforts. Inappropriate transfers to intermediate neonatal cardiology units have been also avoided, referring the baby directly to the regional cardiac surgery service at FTGM HUB, when necessary. Finally, telemedicine allowed pediatric cardiologists at SPOKE centers to improve their skill through the interaction with experienced and specialized colleagues at HUB center.

The main drawback, limiting the full application of the network, depends on the training needed for using new technology but also on the willingness of operators to dedicate extra time, at least initially, for telemedicine-based examination.

The extension of use of tele-echocardiography in fetal diagnosis of cardiac malformations would allow early diagnosis for planning care and interventions already at delivery time at the specialized center. Moreover, the telemedicine network, now focused on pediatric cardiology, could be extended to other medical pathologies, also in adults just providing remote specialized medical care around the region [24–29].

Advances in information technology and lower costs allow telemedicine empowerment according to the needs of physicians also outside the hospital setting.

Acknowledgements

Thanks to Lions Clubs of the District 108La (Tuscany) and to the Lions Clubs International Foundation (LCIF) for financially supporting this project, particularly to Dr. Gianluca Rocchi, Lions District 108La Governor in 2014/2015, for promoting and supporting the implementation of the network.

We thank for collaborative effort both clinical, technical, and administrative teams of clinical centers participating to this project; the list of the main collaborators (clinical, technical) is as follows: Elba Hospital (Bruno Graziano, Duilio Biani and Alberto Iurato, Marco Galletti), Lucca (Andrea Azzarelli, Riccardo Orsini), Empoli (Anna Monopoli), Pontremoli (Mauro Cozzalupi, Renzo Bresciani), Arezzo (Marco Martini and Rossella Brandini, Maurizio Pasquini), Bibbiena (Moreno Marri), Montepulciano (Jessica Attene), Prato (Pierluigi Vasarri and Anna Maria Traini, Fabio Noferi), Pistoia (Michela Taglioli), Pescia (Stefano Di Marco), Pontedera (Laura Papi), Grosseto (Alberto Cresti), and Viareggio (Elisa Ferrali).

Special thanks to the pediatric cardiology staff at MEYER Pediatric Hospital (Silvia Favilli; Marco Curradi), recently involved in the project.

Finally, thanks to the FTGM staff (clinical, technical, and administrative), particularly to Giuseppe Santoro (pediatric cardiology), Bruno Murzi (pediatric cardiac surgery), and Medical Informatics collaborators in Massa e Pisa (Maurizio Mangione, Gianna Alberini, Mario Cossu, Mauro Micalizzi, Giacomo Piccini, Emiliano Rocca, Tiziano Carducci, Andrea Gori, and colleagues).

Conflict of interest

The authors declare no conflict of interest.

Funding

This project ("Arriviamo al Cuore di Tutti") was jointly financed by Lions Clubs of Tuscany region and the Lions Clubs International Foundation (LCIF, www.lcif.org), under the promotion of regional healthcare authorities. A grant of 71.000 US$ (GA 14451/108-LA) was provided from the LCIF in 2015, in addition to the contribution of local Clubs, up to a total project budget of 170.000 euro.

The FTGM, supported by the Lions Clubs and LCIF and promoted by regional authorities, contacted the main healthcare institutions throughout Tuscany for planning implementation of tele-echocardiography service. Formal agreements were set up for experimentation defining legal issues for care delivery cooperation in pediatric cardiology. The regional technical healthcare organization (ESTAR) was contacted for scheduling, in collaboration with FTGM informatics staff, VPN networking, and installation of workstations at SPOKE centers.

The financial budget, provided by Lions/LCIF, was sufficient to purchase hardware and software for implementing telemedicine workstations in each SPOKE, while technicians from both FTGM and the regional health system organization jointly contributed to set up the HUB-and-SPOKE VPN network.

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