T@HIS: A satellite based telemedicine network for imaging teleconsultations

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Abstract

T@His is an ESA (European Space Agency) project for the deployment of a telemedical network connecting physicians and hospitals over a new-generation satellite network based on the AmerHis payload on the Hispasat Amazonas satellite. The consortium is formed by Thales Alenia Space España (Spain), Fraunhofer IGD (Germany) and CETA (Center of Excellence in Advanced Technology of Rio Grande do Sul in Brazil). The project objectives are to extend current medical network connecting isolated areas in Amazon over satellite communication. The project involved three remote sites in isolated areas and one site in urban area. In total four satellite terminals have been deployed at Porto Alegre (referral hospital in southern Brazil), Breves, Portel and Gurupá. All three spokes are located in Pará state, in northern Brazil.

Key words: *Telemedicine; Teleradiology; Referral and Consultation; Remote Consultation; Satellity.*

Resumen

T@His: Una red de telemedicina para la teleconsulta de imágenes vía satélite

T@His es un proyecto de la ESA (Agencia Espacial Europea) para el despliegue de una red de telemedicina con el objetivo de conectar médicos y hospitales a través de una red satelital de nueva generación con base en la carga útil AmerHis, en el satélite Hisapasat Amazonas. El consorcio está formado por Thales Alenia Space España (España), Fraunhofer IGD (Alemania) y CETA (Centro de Excelencia en Technologías Avanzadas de Rio Grande do Sul, en Brasil). El objetivo del proyecto es ampliar la red médica actual conectando áreas aisladas en la región amazónica mediante un satélite de comunicaciones. El proyecto abarcó tres sitios remotos en áreas aisladas y un sitio en un área urbana. En total, se desplegaron cuatro terminales satelitales en Porto Alegre (un hospital de referencia en el sur de Brasil), Breves, Portel y Gurupá. Las tres últimas localidades se encuentran en el estado de Pará, en el norte de Brasil.

Palabras clave: *Telemedicina; Consulta Remota; Telerradiología; Remisión y Consulta; Satélite.*

Resumo

Uma rede de telemedicine para teleconsultoria de imagens via satélite

T@His é um projeto da ESA (Agência Espacial Européia) para o desenvolvimento de uma rede telemédica conectando especialistas e hospitais, com uma nova geração de redes de satélites, baseado no AmerHis com carga sobre o satélite Hispasat Amazonas. O consórcio é formado pela Thales Alenia Space España (Espanha), Fraunhofer IGD (Alemanha) e CETA (Centro Excelência em Tecnologias Avançadas do Rio Grande do Sul, Brasil). O objetivo do projeto é aumentar a rede médica atual conectando as áreas do Amazonas através de uma rede de comunicação por satélite. O projeto envolveu três locais remotos em áreas isoladas e um local na zona urbana. No total, quatro terminais de satélite foram implantados em Porto Alegre (hospital de referência no sul do Brasil), Breves, Portel e Gurupá. Os três estão localizados no Estado do Pará, no norte do Brasil.

Palavras-chave: *Telemedicina; Telerradiologia; Referência e Consulta; Consulta Remota; Satélite.*

INTRODUCTION

The dominant type of images transferred over the system is ultrasound images, acquired from portable or stationary ultrasound devices. The medical applications include general examinations as well as obstetric and gynaecology. However the applied platform handles any imaging modality and particularly DICOM formatted data. The medical platform deployed is based on TeleInViVo[1], a research project funded by the European commission. TeleInViVo encompasses a portable ultrasound device and a personal computer and provides various communication links for medical data exchange. Presently the application is enriched with a teleconference tool providing physicians with a real-time face-to-face communication. The software on the mobile computer is capable of acquiring medical ultrasound images from the ultrasound device and storing them in the local medical database.

SYSTEM OVERVIEW

The medical network that was deployed in this project consists of different hardware and software components that together offer the special services needed for a comfortable medical collaboration. All collaborative services including video-conferencing and the medical image acquisition and analysis are performed by the TeleConsult[2] application, as described in the following section. The selected remote regions in Para state have no access to broadband terrestrial communications. Therefore, the connection between the different TeleConsult users is established via the satellite system AmerHis.[3] AmerHis is the first regenerative DVB-RCS satellite platform and it was designed as a response to cover the growing demand in multimedia broadband services and the adaptation of real-time services to the satellite world.

AmerHis allows the establishing of a connection between the end-users without transferring data over a centralized hub. This is realized with the help of onboard processing. So the delay of connections can be reduced by the half and real-time applications like Voice over IP are possible. It permits direct meshed communication between four coverage areas (Europe, South America, North America and Brazil), and also broadcast and multicast transmission, for example from one to all beams, thanks to its on-board packet replication capacity.

AmerHis DVB-RCS user terminals can transmit up to 4 Mbps and receive up to 8 Mbps allowing the deployment

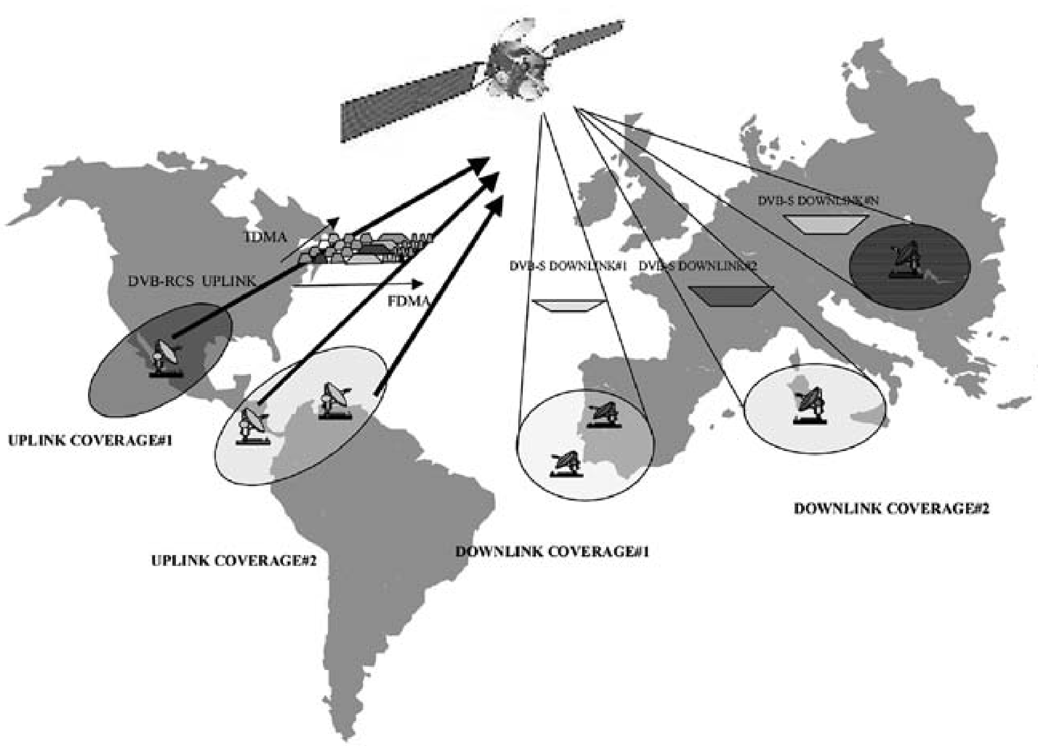

Figure 1 - AmerHis Full Multi-beam Cross Connectivity.

of any IP application (for example Internet/Intranet Access and Virtual Private Networks between terminals) and is interoperable with the terrestrial networks.

The architecture of the system is based on different dynamic QoS classes to differentiate the traffic and to be able to offer different SLAs to customers.

The AmerHis system integrates a Broadcasting Multi-Media network with an Interaction network by combining two standards, the DVB-S and DVB-RCS, into one unique regenerative and multi-spot satellite system. In this manner, the users calling for broadband and interactive services are able to utilise standard stations (RCSTs) at both transmitting and receiving sides. In this system, the DVB-RCS return channel standard is applied by all users to access through a standard uplink to the satellite. On board, the regenerative payload (OBP) is in charge of multiplexing that information from diverse sources into one or more DVB-S data streams capable of being received by any standard IRD equipment. The on board repeater is not only capable of multiplexing signals coming from the same uplink, but also cross-connecting and/or broadcasting channels coming from separate uplink coverage areas to different downlink coverage areas.

AmerHis does not only provide a geographical extension to the medical health care system, but also offers tools for comfortable medical collaboration and the possibility of sending/receiving information from/to Internet.[4-7] For this purpose, the following services were provided:

- Data Exchange
- Shared view
- Annotation Exchange
- Chat
- Voice Tools
- Video Conferencing
- Multimedia Messages

SYSTEM ARCHITECTURE

The medical network consists of two main modules, the TeleConsult Platform and the Satellite Platform. Both modules are connected to each other through a communication network.

Teleconsult Platform

The TeleConsult system is divided into the acquisition modules and the teleconsult software (2D and 3D imaging viewer) and jabber communication module.[7,8] The acquisition module used for acquiring the medical images from the ultrasound device. The ultrasound devices are equipped with an analogue video output. The ultrasound's video output is connected to our software acquisition module through a video grabber, as illustrated in the Figure 3.

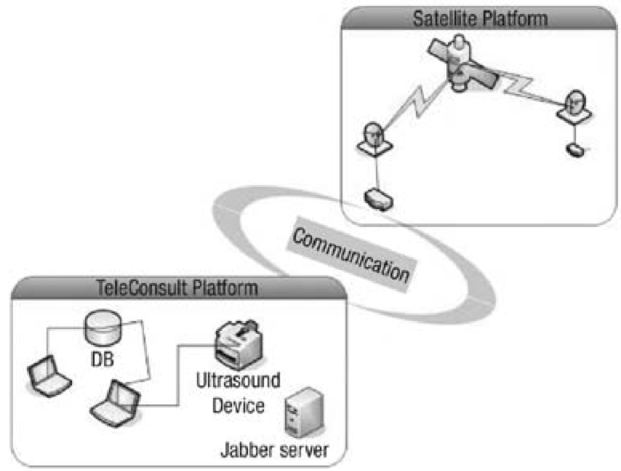

Figure 2 - System Modules.

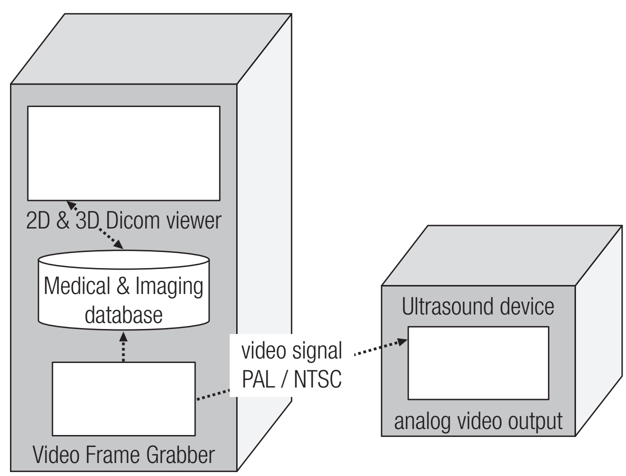

Figure 3 - Acquisition modules over video frame grabber.

TeleConsult software: every physician at the different locations uses the software TeleConsult for loading, processing and analyzing image data and for exchanging data and annotations with other physicians. TeleConsult delivers an implementation based on the DICOM protocol for sending medical image data. Different services for communication are provided by this software to facilitate the medical collaboration. Furthermore the software provides an interface for transferring image data from a stationary

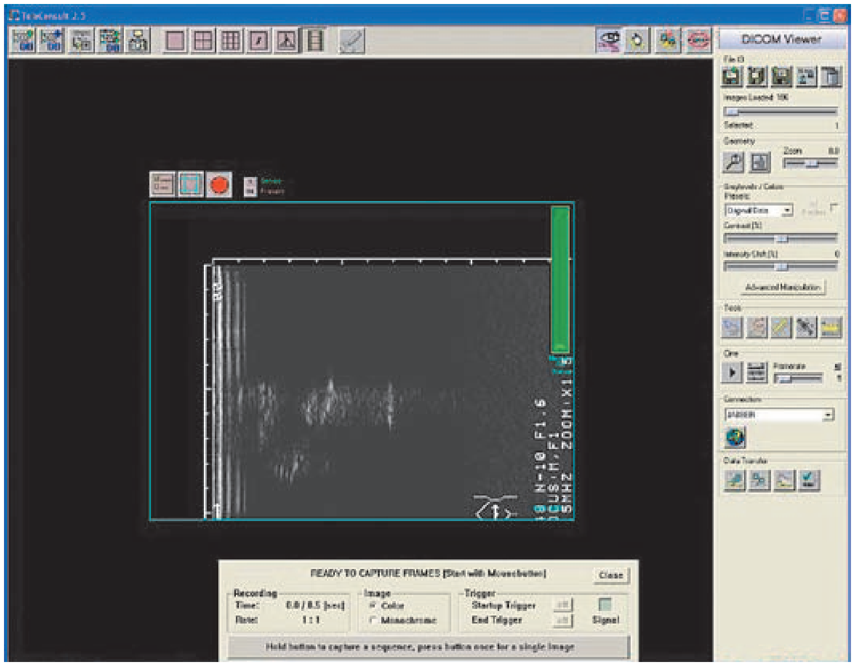

Figure 4 - GUI of acquisition modules.

ultrasound device to the software. The medical application has been deployed to four clinics. Furthermore, a Jabber server needed for the communication and exchange of medical data has been installed.

Satellite Platform

AmerHis system can be divided into the space segment and the ground segment. The ground segment consists of three different components:

- The management system to configure and manage the network.
- Gateway interfaces to terrestrial services
- The user terminals to access the system

The overall satellite system architecture is depicted in Figure 6. It consists of 4 nodes, interconnected through satellite communication (DVB-RCS over AmerHis). The central / referral hospital is located at Santa Casa Hospital in Porto Alegre. The rest three installations are placed at Breves, Portel and Gurupá

The Santa Casa Hospital in Porto Alegre provides an Internet gateway for the nodes behind the satellite network. A network infrastructure is already available in the hospital with 100Mbps.

SERVICE MODEL

The description of the service provided can be summed up as the following:

- Four sites interconnected.
- One of the sites is considered as reference hospital for 1st and 2nd opinion diagnosis.
- The access to the remote hospitals is not easy and requires a non-negligible transport time (from hours to days).

The solution proposal for T@His network is offering full cross connectivity between the sites and Internet connection through the reference hospital. This network is based on:

- DVB-RCS standard terminals.
- Connectivity provided through the AmerHis payload boarded in the Amazonas satellite.

To provide a sustainable model the solution proposed has to be more cost-effective than the existing situation where the doctors have to travel. The new service model replaces only partially the travel of doctors from the reference hospital to the remote hospital. It is notintended to replace it completely as the contact doctor-patient has to be kept.

The goal is to reduce 50% of travels by using the Tele-Consult application by having two days per month com-

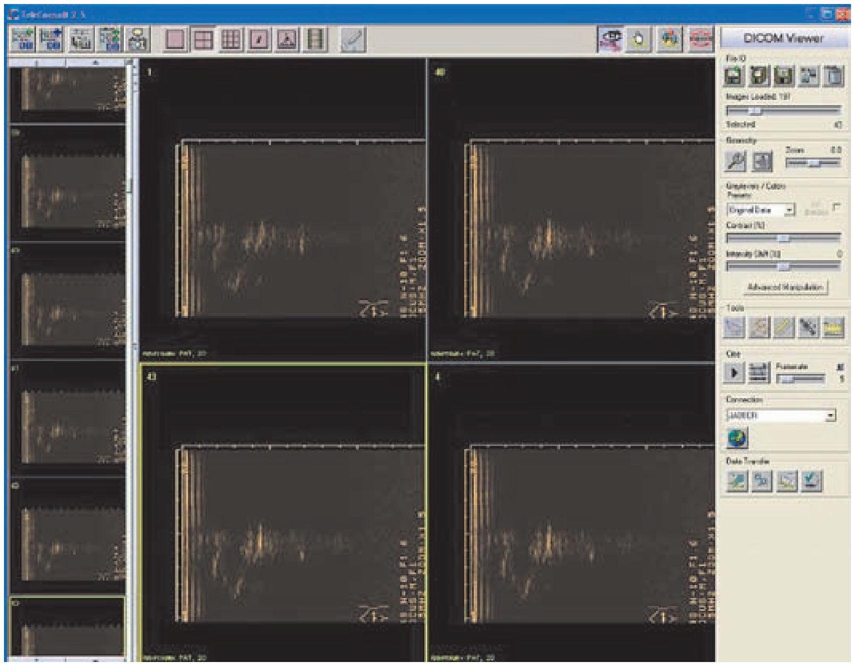

Figure 5 - Ultrasound imaging viewer.

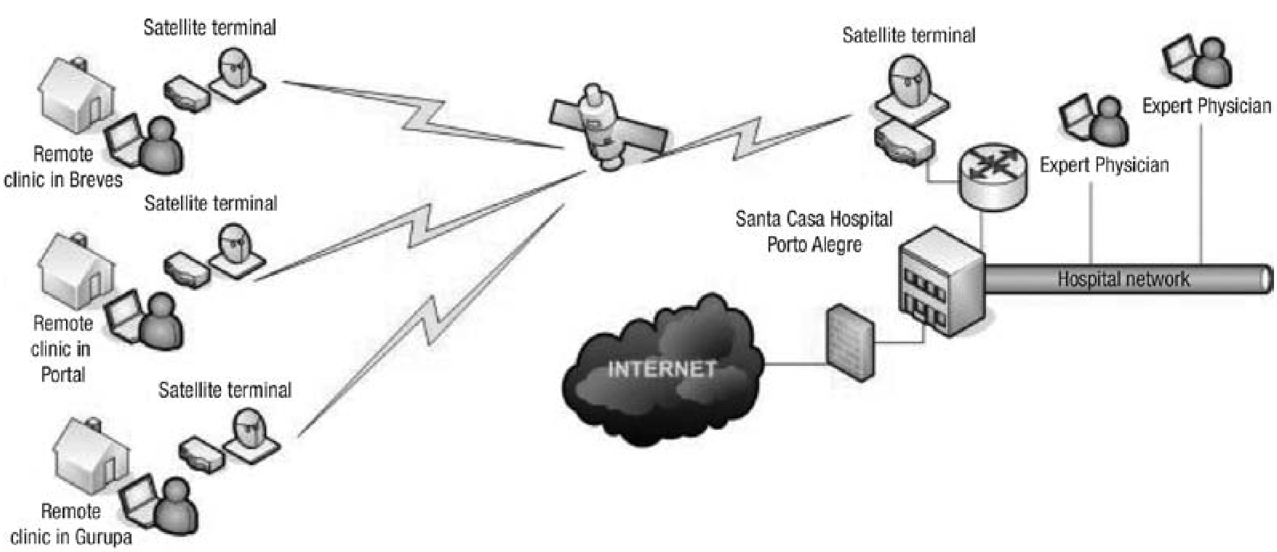

Figure 6 - Overall System Architecture.

pletely dedicated to the remote hospital. This model keeps the same service level but with another advantage. The two days don't have to be used by the same specialists as it happens when the doctor travels. These two days can be managed differently depending on the patients' needs.

During the T@His project it has been shown that the evolution of the existing medical networks towards a model where the satellite replaces partially the remote assistance of hospitals provides benefits in terms of economical and social value.

The high cost of the bandwidth is here justified by the high costs of transport to attend patients in areas which are far from the reference hospital of the area. The higher number of remote sites with the service the more value is obtained by the institution in charge of providing the service. After a successful pilot our advice is to upgrade the network up to ten sites and then get some feedback of the quality of the service. If this is ok the upgrade can then be done to fifteen and then to twenty.

T@His offers a health telematics platform for cooperative work and transfer of medical data via satellite (DVB-

RCS) communication channels. The technology allows the transmission and analysis of 2-dimensional as well as video conference functionality between physicians. The interactive videoconferencing over T@His used for teleconsultations, allows telepresents of a distant physician or of other healthcare professionals. What is more, an accompanying exchange of documents overcomes and solves the manifold problems of media discontinuities in medicine. By this, T@His improves the exchange of medical reports, second opinions and treatment options within the physician-to-physician communication. The platform is created to be used in the field of the ultrasound examinations.

However, it can be also adapted to the specifics of all other segments of the medical imaging market that is the long term objective of T@HIS consortium.

T@HIS platform offers different applications:

- Second Opinion: for online or offline collaboration concerning suspicious patient cases.
- Remote Reporting: for sending of imaging reports, that can be reviewed by remote physicians either in real time or later, using the system's store-and-forward capabilities.
- Interdisciplinary Communication: for virtual meetings among doctors from various specializations.

All this applications together present a complete telemedicine solution. The T@His applications are established in internationally interoperable form, so the transferred information can cross any national border as easily as any distance. Through this T@His provides many starting points for supporting treating doctors in making difficult decisions and for enhancing their specialist knowledge.

DEPLOYMENT AND FIELD TESTS

The scope of this phase was to perform the system deployment in Brazil. The system evaluation concentrated on the evaluation of key characteristics of the T@HIS system regarding its functionality, reliability, usability during its evaluation in test cases in the pilot performed among the cities of Breves, Gurupa, Portel and Porto Alegre. Evaluation included software and hardware evaluation, and independent evaluation activities to ensure the functional completeness of the configuration items against their requirements and the physical completeness of the configuration items.

The deployment started with the installation to the Santa Casa Hospital. Satellite terminals and antennas were installed. In addition, the terminals were connected to the existing hospital network and provided a gateway to receive and transmit data to and from the Internet.

Furthermore, TeleConsult including NetMeeting application was delivered to the hospital. The software was installed on computer where the expert doctor is providing the medical services. Web video cameras and headset were delivered to the doctor. In the case, where computer was not available a PC was provided by IGD for the operation of the teleconsultations.

Accomplishing the installations and configuration in Porto Alegre we continued with the deployment in Breves hospital. The deployment included the installation and configuration of the necessary hardware and software. TeleConsult application was installed on the hospital PC and the PC was connected to the ultrasound device.

The field tests included medical teleconsultation and particularly transmission and reception of medical data. Different services for synchronous and asynchronous collaboration were tested. During field tests all collaborative services, already tested in lab tests, were tested again.

It should be mentioned that the pilot participants were given training sessions of the TeleConsult application including the basic operational functionalities of the software. CETA with the help of Santa Casa Hospital performed the training sessions. CETA visited the remote sites frequently for training and IT assistance.

During execution of the pilot projects, physicians involved completed the response forms in order to record feedback and evaluation in a number of attributes and quality characteristics of the system. This is considered useful in order to measure the progress made from the pilot phase and also to find out where the system is weak and needs more attention.

However, the twenty (20) teleconsultations on ultrasound examinations performed between Santa Casa hospital in Porto Alegre and Breves hospital in Para states were recorded in a single day, assisted by a technician from CETA, due to the physician lack of time. Although the pilot involved 3 rural areas in Amazon only one site was able to use the system.

The outcomes of the evaluations reports of the (20) teleconsultations shown that the physicians performed six (6) *online* teleconsultations and fourteen (14) offline teleconsultations (see figure below). All the examinations based on 2D ultrasound imaging. 3D ultrasound acquisition was impossible by that time due to the fact that the remote hospital had no 3D ultrasound device.

Table 1

Hospital	Number of tele-consultations	Comments
Breves	20	Many delays in the usage of the system. Due to frequent change of medical staff
Portel	0	No medical staff available
Gurupa	0	Defect satellite terminal. The terminal was not replaced on time as the Brazilian beam of Amazonas satellite was shutdown

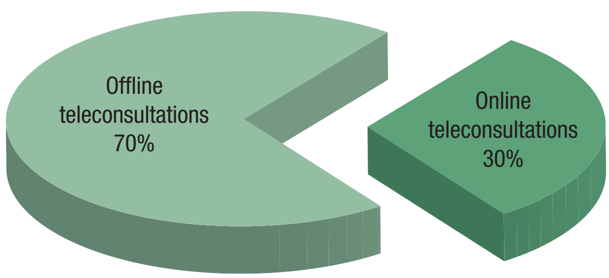

Figure 7 - Online vs. offline teleconsultations.

In table below (Table 2) the types and the number of medical examinations is depicted. The average medical data transfered from one site to the referral hospital was about 102.54 KB per teleconsultations.

Table 2

Type of examinations	Number of teleconsultations
Abdominal	3
Obstetric	9
Urological	4
Gynaecological	4

Table 3

Type of ultrasound imaging	Number of teleconsultations
2D – Two dimensional	20
3D – Three dimensional	0

The physicians exchanged only a few ultrasound frames, where the diagnosis was unclear. The average time of the teleconsultations were about ten minutes, according to the expert physician. Figure 8 illustrates the percentage of each type of ultrasound examinations performed.

The results above presented demonstrate the benefits an application of T@His system. However, the utilization of

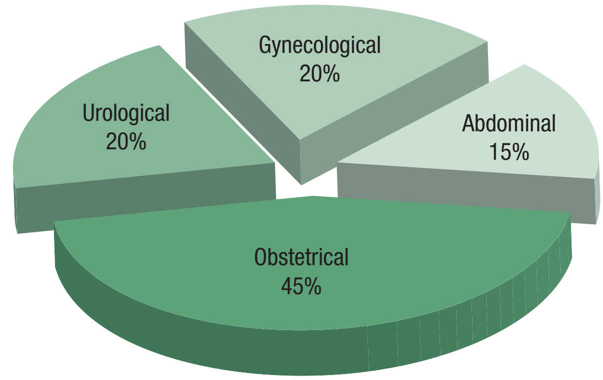

Figure 8 - Type of ultrasound examinations performed by the remote physician.

the system has been quite scarce for the following reasons (recommendations addressed in Lessons Learnt section):

- The medical staff that received training had only little or even any knowledge about how to use a computer;
- The medical staff that received training didn't have any knowledge or practice about the ultrasound equipment;
- During the practical training the physicians were conducted to operate the TeleConsult system, but didn't want to operate this equipment;
- Medical staff rotation is high, and the trained ones remained few time in the location where they received trained. Lack of interest between the physicians with permanent positions;
- Scarce time to attend each patient;
- Constraints regarding replacement of equipments.

CONCLUSIONS

For future network upgrades or new telemedicine projects, we recommend taking into account the lessons learnt during T@His. The three sites in Para are really remote and were a big challenge both in terms of training the local users (physicians and/or computer technicians) to operate the system and specially in motivating physicians to use the system. The physicians' situation is really different from Europe and need to be taken into account, for example the frenetic rythm, a patient each five minutes, that gives the physicians no time (and motivation) to use the system in real time. Physicians are a very rare resource in those locations and when one is available at one of those centers, they have to take care of several cases. T@HIS project team, every time a new physician was coming to remote places, provided a technical system demonstration how the physician can use the request second opinion from an expert physician. However, the physicians were not in the position to use the system due to their workload at the hospital seeing patients.

Although the physicians knew the benefits of the operating the offered system, they were not able to use it due to time limitations.

The conclusion is that when a telemedicine is in place the whole system infrastructure and physicians examination workflow must be adapted and also officially supported by health care system.

The technical skills in some remote areas are scarce, so the system need to be as much as posible a “plug-and-play” and “fool-proof” one, including the maximum level of detail in user manuals and FAQs. The deployed telemedicine system is easy to use as it has been demonstrated to the physicians. However, the physicians had to spent sometime with the application and learn how to use it and also explore new functionalities. It seems that physician never invest the proper time for learning the medical application and understood the basic functionalities and operations offered.

It is key to establish a strong link between physicians in the remote sites and the ones from the larger hospital providing second opinion and teleconsultation remotely. It would be even better if there is already some previous joint work or collaboration between the involved hospitals, since it has a major impact on the effective system utilization. Regarding future telemedice boosts, it is very important to involve the main hospital in the selection process of sites where the teleconsultation would take place. It is also necessary to contact physicians with a permanent position at an hospital and to get from them the commitment to use the system before performing an installation at one site.

This remote locations present difficulties to communicate between even by phone, so teleconsultation need to be carefully arranged in advance and a strong commitment between parts to attend the planned events is necessary.[9]

T@His project has also found constraints regarding replacement of equipments. People involved in the project has been trained to install, configure and use the application, but the experience has taught the project team the need to extend this training also for HW, as well as the need to have accesible spares of every equipment in the project, specially in the locations that are more remote.

An interviewed physician gave T@His team the following feedback, they are really interested in the videoconferencing system, as to exchange opinions in real time. Doctor’s interest in formation is also shown; they are not able to attend congresses or presentations, while they could participate and learn from them by including some popular congress site to the telemedicine network, integrating both telemedicine, with physicians countinuous need for diagnostic and therapeutic needs.

T@His team have gained important experience as the problems we faced are challenges that need to be deal with every time we want to run a teleconsult system on remote and underdeveloped areas. These leassons learned need to be taken into account for future/starting projects (for instance MedNet in the frame of FP7).

Summarizing, It has been shown that one of the most crucial issues to ensure the project success is studying deeply the region needs, involving doctors from the beginning to the end of the project. Furthermore, to guarantee the sustainability of the system, it is essential not only the appropriate installation of the system, but also the system maintenance.

ACKNOWLEDGMENTS

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