

Experience of a Real-time Tele-EEG Service

N. Lasierra, A. Alesanco, C. Campos, E. Caudevilla, J. Fernández and J. García

Abstract—This paper reports an experience in the setting-up and evaluation of a telemedicine solution to provide an electroencephalography service between a secondary hospital placed in Calahorra (Calahorra Hospital Foundation, FHC) and a tertiary hospital placed in Logroño (San Pedro Hospital, HSP) both in La Rioja, Spain. We have evaluated technical and clinical aspects of the tele-EEG (electroencephalography) service as well as the impact over patients, health staff and hospital organization for 6 months. During this period, there have been performed a total of 116 clinical consultations. With reference to patients' opinion, 98% of them stated to be satisfied with the new tele-EEG system and 75% of them preferred it rather than the conventional one, due to they reduce traveling expenses and the total invested time in the EEG test. This new service has been also very appreciated by medical staff, who assure thanks to the tele-EEG service the access for patients to this type of clinical test is improved.

I. INTRODUCTION

The EEG test is a non-invasive neurophysiology exploration usually needed in many neurological consultations to configure a final diagnosis, together with the information from patient's clinic and neurological exploration. The EEG-test records the electrical activity of the brain to provide information used in the diagnosis of different clinical circumstances such as epilepsy or mental disorders. Moreover, it is used to analyze and control the treatment of patients with neurological damage. It is usually performed with an ambient video recording in order to clearly distinguish biological artifacts from neurological alterations and also to advise in advance epileptic seizures. Although the EEG test is a highly demanded medical technique, used in different medical fields like neurology, internal medicine and paediatrics, this service is not available in many primary or secondary hospitals. Thus, the introduction of a telemedicine system applied to acquire and transmit electroencephalographic signals in real time is presented as an attractive solution to avoid patient's transfer to tertiary hospitals and to provide them better access to this clinical test.

This work has been partially supported by project TIN2008-00933/TSI from *Comisión Interministerial de Ciencia y Tecnología* (CICYT) and *Fondo Europeo de Desarrollo Regional* (FEDER) and partially by project PET2006-0579 from *Programa de Estimulo de Transferencia de Resultados de Investigación* (PETRI)

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During the last years, some experiences or studies about digital EEG signal transmission have been performed [1]. Some of these studies report that an electroencephalography tele-consultation can be done through a real-time system or using store and forward methods over diferents communication lines [2]. One of these experiences, the first one, was in Canada where EEG data transmission was done over a telephone link [3]. Despite real time telemedicine is the most interesting application to transmit the EEG signal (because the neurophysiologist can advise and report about abnormal situations at the same moment they occur, thus it is possible a fast reaction in a critical situation or if patients need medical assistance), it should be noted that the use of these systems is not widely extended because they need more technological resources as a high-speed communication network to work correctly. For that reason, most of the recent experiences of tele-EEG are based on store and forward systems.

In this paper we report an experience of real-time tele-EEG in La Rioja, Spain. A tele-EEG system has been set up between a secondary hospital placed in Calahorra (FHC) and the neurophysiology department from San Pedro Hospital in Logroño (HSP), 55 km far away from it. The latter is the tertiary hospital where patients were referred for the EEG-test before the telemedicine system was implemented. To the best of our knowledge, this is the first real-time tele-EEG experience in Spain.

II. METHODS

A. Tele-EEG System Architecture

The general architecture of the tele-EEG system can be divided in three modules as it is depicted in figure 1. The first part is the data acquisition device (NicoletteOne cEEG Module from Viasys) composed by an electrode hat used to register the EEG signal and a video recording camera, both connected to a PC where the control software is installed. The second part is the reading station. Both parts are placed in the FHC and are linked through the LAN (Ethernet 100baseT) available in the hospital. The software StudyRoom from Vyasis has been installed in the reading station, thus the neurophysiologist can visualize the acquired data. Additionally, this station includes two 200 Gb hard disks to store the EEG test, so that this second part constitutes a backup system too. The StudyRoom software provides also a whole set of tools that can be used by the neurophysiologist to enhance the diagnosis accuracy, e.g, tools for frequency and amplitude measurement. Finally, the third part, placed in Logroño is the neurophysiologist's PC used to control in a

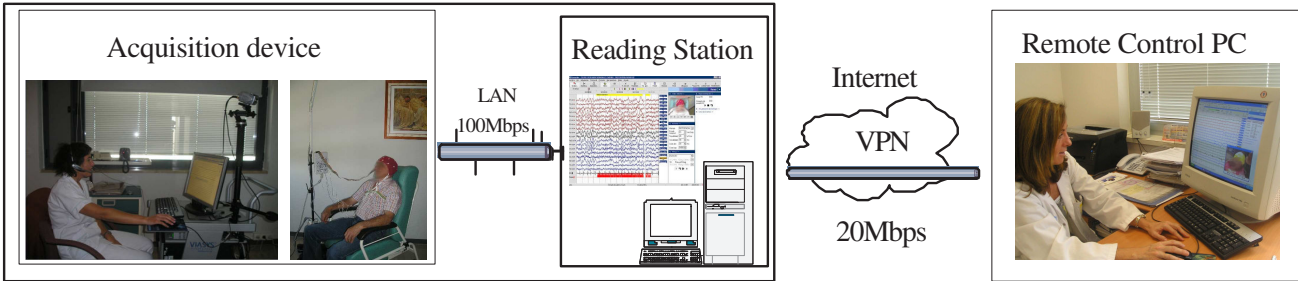


Fig. 1. Tele-EEG system

remote way the reading station through the Teminal Server. The EEG data and the recorded video are transmitted at the same time that information is being acquired thus the neurophysiologist can revise it in real time using the remote control. Once the test is over, it is transferred to the FHC store server. Therefore, the neurophysiologist can revise the test again whenever it is required. A Virtual Private Network (VPN) has been established between the two hospitals in order to connect both places and guarantee the security in the communications. The available bandwidth is 20Mbps.

B. Tele-EEG procedure

At present, a nurse is in charge of carrying out the EEG test in the FHC under the supervision, in real time, of a neurophysiologist from Logroño through the telemedicine system. Therefore, patients are scheduled to perform the EEG test in the FHC, where the nurse (who has been trained on EEG acquisition in the Neurophysiology department of Logroño) prepares the required equipment, the patient, and carries out the test in the way the neurophysiologist guides her. The interaction between both professionals is done through a telephone call, using a hands-free head set, that will not be finished until complete the entire EEG test. Hence, it is guaranteed the test is done in the correct way and a fast reaction in alarm situations.

The screen displayed in the neurophysiologist’s PC is shown in figure 2. Apart from the selected EEG assembly (different combinations of the acquired data can be shown) the ECG signal is also displayed (which provides important useful information in heart attack situations) and the ambient video. The ambient video and EEG data synchronization at the reception site is very important, because the information extracted from both will help the neurophysiologist to advise and correctly report abnormal situations.

C. Evaluation

We have conducted a complete evaluation plan in order to study some technical, clinical, economic and social aspects related with the tele-EEG system introduction. This is a necessary process to demonstrate technical and clinical viability as well as to determine the improvements for patients and changes over medical staff and hospital organization. This evaluation process has been divided into two phases: Viability study and Impact study [4].

- 1) Viability Study: In order to determine the viability of the telemedicine system, we have performed two different studies: a technical evaluation and a clinical validation
 - Technical Evaluation: The aim of this process was to determine the technological resources needed (such as the necessary bandwidth) to guarantee real-time communications or ambient video and EEG signal synchronization as well as to evince and control that technical aspects worked without problems that compromised the diagnostic procedure. Although this study was completely performed before the set up of the telemedicine system, we designed two questionnaires to be filled by the health staff (one for the nurse and one for the neurophysiologist) to control the technical effectiveness of the system in daily consultations. These tests report information such as the level of video and data EEG synchronization, video and EEG quality, time dedicated to carry out the test or the number of technical problems that occurred during the medical consultation.

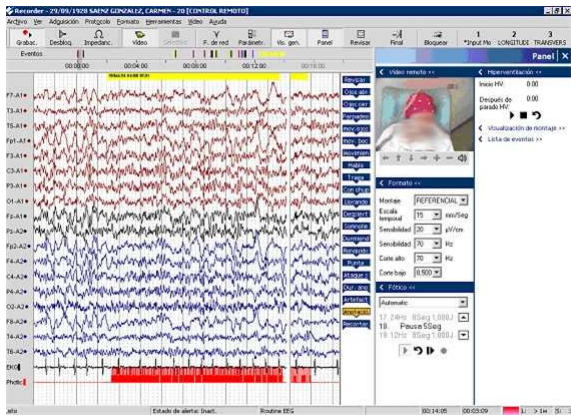


Fig. 2. Study Room’s application screen

- **Clinical Validation:** We have performed a clinical validation in order to demonstrate that the slight quality decrease the Terminal Server produces (used to remotely control the reading station), does not affect the neurophysiologist's assessment and the diagnosis offered with the telemedicine system is the same as the offered with the traditional procedure. In this study the neurophysiologist was requested to evaluate different clinical aspects such as general electroencephalography activity or alterations observed during the hyperventilation stage for both, telemedicine and traditional, procedures.

2) **Impact Study:** The purpose of this phase was to collect information to determine the level of success of the tele-EEG system introduction. Patients were surveyed in order to get information about economic aspects, the invested time, and their opinion about the tele-EEG service. To gather this information and also health staff opinion, we designed some questionnaires. These tests included some questions about traveling expenses, invested time, the way of transport or patients preferences. Thanks to this information it has been possible to make a comparison about some economic aspects consequence of the system (telemedicine or traditional) choice.

III. RESULTS

The tele-EEG service was set up 6 months ago. During this period, 116 consultations have been carried out. The neurophysiologist and the nurse involved in the project expressed their satisfaction with the telemedicine system. They consider it is easy to use, intuitive and that very good interaction is possible between them. They especially point out the improvement it implies for the patients' access to this type of clinical test.

A. Viability study results

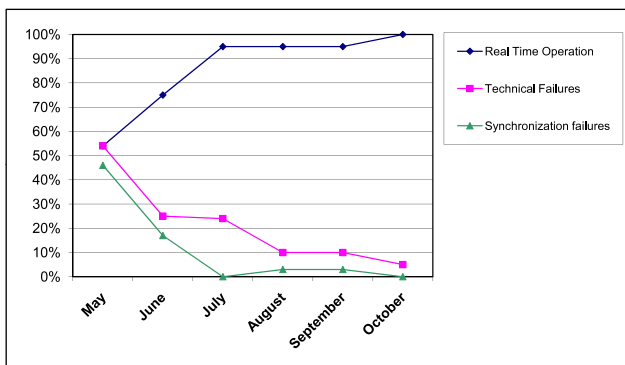


Fig. 3. Technical problems evolution

Technical evaluation results have been summarized in figure 3. Some technical failures, like EEG and video synchronization or delay troubles in the ambient video, occurred during the first months. The rate of these incidents has been

eventually decreased rapidly whereas the percentage of consultation where real-time functionality was guaranteed has been increased. Most of these technical problems were solved thanks to the improvements done over the communication network. It is interesting to point out the mean bandwidth needed for a tele-EEG session was 5.8 Mbps.

The EEG test was always performed in a safe manner and the neurophysiologist could express a clear diagnosis assessment for all the tele-consultations done despite these technical troubles. In fact, EEG register quality was very high for all the tests done and in none of them video quality was poor.

The clinical validation turned out to be a complete success. A total of 20 tests were included in the clinical validation: twelve basal EEG and eight sleep EEG studies. Eight of the basal EEG tests were normal and four presented different pathologies. Regarding the sleep test analyzed, half of them had pathological findings. The neurophysiologist assured there were no significant differences between information extracted from each pair of compared EEG tests (telemedicine and viewed locally one) and she provided the same diagnosis assessment for all studied aspects in both tests.

B. Impact study results

The main characteristics of the 116 consultation done through the tele-EEG system are represented in table I. At present, one day per week is reserved for the tele-EEG consultations. A total of 5 EEG sessions are usually performed every week, although this number can be varied depending on the type of test done (basal or sleep) or due to the introduction of an urgent patient.

TABLE I
TELE-EEG SESSION

EEG type	Non admitted Patients	Admitted Patients
Basal	95	11
Sleep	7	3

As it is shown in table I, a total of 14 tests were done to inmate patients in the FHC. Although it just represents the 12% of the tele-consultations done, it should be noted that about 1260 € were saved in ambulance costs (the ambulance cost for one patient's transfer is about 90 €). Eventually, the amount of money invested for admitted patient's transfer is expected to be lower thanks to the introduction of the tele-EEG system and the expansion of the hospital wards for the neurology service.

Although 116 consultations have been performed with the telemedicine system, some patients did not fill the questionnaires because some of them were elderly people (over 80), others did not speak Spanish or they were in an emergency situation. Thus, we report in this section the results extracted

from 67 patients' questionnaires. The distribution in five age-groups of the surveyed patients is presented in table II. As stated by patients' opinion the tele-EEG system provides a comfortable and easy way to access this medical test. 98,3% of them would use it again and 82% of them prefer tele-EEG consultations rather than conventional by reason of this system avoids patient's transfer, reduces invested time and offers a fast service with the same diagnosis results. Mean waiting time for patients to receive the EEG test diagnosis results has been also considerable reduced due to the organizational changes and the communications improvement between health staff from both hospitals (FHC and HSP) as consequence of the Tele-EEG system introduction.

TABLE II
PATIENTS AGE GROUPS

Item	0-14	15-29	30-44	45-60	over 60
Age	5	17	12	12	21

TABLE III
COMPARISON BETWEEN THE CONVENTIONAL AND THE TELE-EEG SYSTEM

Item	Tele-EEG	Conventional
Traveling expenses	3,3€	17,8€
Average time dedicated for patients to the EEG-test	1h 10 min	3h 45 min
Mean consult time	47 min	45 min
%Patients losing working hours	32%	40%
Total working hours lost	1h 37 min	4h
Mean number of companion person	1	1
% companion persons losing working hours	31,5%	71,9%
Working hours lost	2h 23 min	4h 20 min
Additional costs (eating,parking)	0€	25,13€

According to the information gathered from patients' questionnaires, we have summarized in table III a comparison about some time and economic aspects obtained as a result of the system used (telemedicine or traditional). As it is exposed in table III, thanks to the introduction of the tele-EEG service, travelling expenses have been reduced in 81% and the whole average of time dedicated for patients to the EEG-test in 68% (this time includes traveling time, waiting time and consult time). Mean consult time is slightly higher with the tele-EEG system because is necessary to establish the phone communication with the neurophysiologist. Total working hours lost has been considerably reduced with the

telemedicine system for patients and companion relatives and additional, costs have been totally saved.

IV. DISCUSSION AND CONCLUSIONS

The tele-EEG service has been set up between the FHC and the HSP hospital with a very high level of success. Nowadays, this telemedicine service is operative and has totally substituted the traditional way used before in the FHC for the EEG test. At present, a nurse is in charge in the FHC of preparation of patients and performing the EEG test that a neurophysiologist supervise in real-time from Logroño. Although there is not a fixed day, one day per week is reserved to perform EEG sessions to patients from Calahorra and nearby areas that require an EEG test using the telemedicine system. However, from now on, there will be reserved two days per week to the EEG test, thus the waiting list for these patients is expected to be considerably reduced. The introduction of this new service has not required significant changes for hospital organization, and the economic resources it implies are just the data acquisition device cost, telephone expenses and nurse training course expenses. It should be noted that this telemedicine system could be also used to perform other specific EEG test such as neonatal EEG or polygraphics recordings if the neurology service is extended and an ICU (Intensive Care Unit) is available for this service in the FHC.

Both patients and medical staff have expressed their satisfaction about the use of this telemedicine service. The success of the tele-EEG introduction is due to the high grade of acceptability it has obtained from them. The number of displacements, cost and the total invested time in the EEG test has been considerably reduced. Moreover, patients feel comfortable with the telemedicine system consultations. The tele-EEG system is a useful solution for patients from Calahorra and nearby areas, and specially for admitted patients in the FHC (so that ambulance costs are saved), handicapped patients (who sometimes refuse to perform the test in order to avoid the troubles the trip implies for them) and patients that need a sleep EEG test (who needed a companion person to drive them to Logroño due to is required for patients not to sleep in the 24 hours before the sleep study test). According to the exposed results, the introduction of this telemedicine system that improves and makes easier the access for patients to this type of medical test has been a completely success.

REFERENCES

- [1] P. Loula, E. Rauhala, M. Erkinjuntti, E. Rätty, H. Hirvonen and V. Häkkinen, "Distributed clinical neurophysiology" *Journal of Telemedicine and Telecare*, vol. 3, 1997, pp 89-95.
- [2] D. Holder, J. Cameron and C. Binnie, "Tele-EEG in epilepsy: review and initial experience with software to enable EEG review over telephone link" *Seizure* vol.12, 2003, pp 85-91.
- [3] House AM, "Telemedicine in Canada" *Canadian Medical Association Journal* vol.117, 1977, pp 386-8
- [4] S. N. Ahmed, C. Mann, D. B. Sinclair, A. Heino, B. Iskiw, D. Quigley and A. Ohinmaa, "Feasibility of epilepsy follow-up through telemedicine: A pilot study on the patient's perspective", *Epilepsia*, vol.49 (4), 2008, pp 573-585