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COMPUTERIZED MONITORING OF DIALYSIS REMOTE SITES AND FOLLOW-UP OF CHRONIC PATIENTS USING SMART-PHONES

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Abstract. This paper briefly describes a possible structure for a complete dialysis monitoring system currently being developed at CSELT with the aim of eventually satisfying the needs of nephrology for telemonitoring.
Of importance is the subsystem related to data acquisition and follow-up of patients undergoing domiciliary *Chronic Ambulatory Peritoneal Dialysis* (C.A.P.D.) which allows patients themselves to forward, from their home, essential treatment data. Symptoms, accidents or consumption of drugs unrelated to therapy can also be monitored. Additional services, such as mailing and remote changing of therapy by the physician, are facilitated. The choice of a suitably programmed smart-phone as the home platform, has demonstrated its potential for telemedicine applications, with a simplification of the patient/user interface.
A trial of this sub-system, called TELEDIAL, is in progress at the G. Bosco hospital in Turin (I).

1. Introduction

There are different treatment options for chronic renal failure patients: haemodialysis, peritoneal dialysis and kidney transplantation. Only transplantation can solve most of the problems of these patients: however, there is always a serious shortfall of donor organs for transplantation.

Haemodialysis is, at least in Italy, the most widespread technique, and requires an external device called “artificial kidney” that utilises appropriate filters to purify the blood through a diffusion mechanism. Peritoneal dialysis, by contrast, exploits a natural membrane as a filter: the peritoneum: there are several techniques, either manual (C.A.P.D., C.P.D.) or automatic (I.P.D., C.C.P.D., N.P.D., TIDAL P.D.) that make use of simpler devices than those used for haemodialysis.

The number of home patients (especially those undergoing peritoneal dialysis) and specialised out of hospital centres (the so-called "Limited Care Centres" [L.C.C.]) is rapidly growing. The diffusion of these decentralised centres is necessary, in order to make health care services more accessible to patients, whilst improving their quality and, sometimes, cutting costs. About 30% of Chronic Renal Failure (CRF) patients carry out dialysis therapy at home or in remote sites.

Each dialysis session produces a series of data issued by dialysis monitors, measuring instruments or hand-set apparatus. In self-managed services, notations that must be taken at regular intervals often give rise to problems and require transcription, increasing the work-load of the already limited personnel. Automatic acquisition of the large amount of data from a dialysis session, could be obtained, for example, by linking the biomedical equipment for patient monitoring to the computer which, together with the utilisation of telematic systems, could offer a viable solution to this problem.

2. Possible structure of a teledialysis system

Multi-choice therapy and the trend towards multi-site decentralised treatment increases the need for means to integrate the management of CRF patients in a consistent manner and which is independent of site and modality.

Teledialysis is a specific telemedicine application, allowing provision of a variety of services. For patients undergoing dialysis in the out of hospital Limited Care Centres, the system could provide "real time" transmission of data from the biomedical equipment, at the patient's bed-side, to the Hospital running the Nephrology Service. This would provide an instantaneous completely automatic remote monitoring of vital parameters relating to live dialysis sessions and with also the possibility of viewing the dialysis room, using a camera. Transmitted data can be directly entered into a computerised record for use in aggregated epidemiological studies or for statistical and mathematical models. For patients undergoing peritoneal dialysis at home, the service could provide a simple method of data entry with the possibility of forwarding them to the referral hospital to be automatically integrated to the record. Furthermore, the exchange of information among different hospital centres, transplantation centres and registry centres at regional, national and international level can also be satisfactorily simplified using telecommunications and the appropriate procedures.

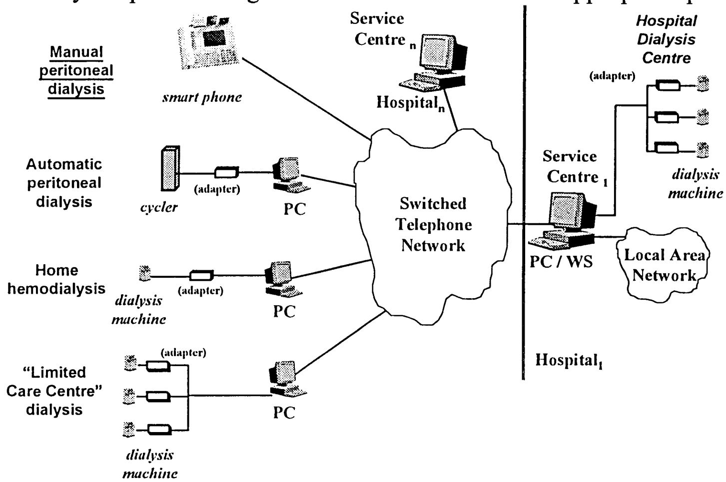

Fig. 1 - Possible local structure of a Dialysis Monitoring System

Figure 1 shows a possible structure of a teledialysis system: this must be an open one that is capable of evolving in order to support increasingly complex configurations and communicating with other outside services. It is composed of hardware for automatic acquisition and transmission of data from biomedical equipment connected to the patient together with software for remote clinical management of the patient. Connection is via PSTN (the "normal" Public Switched Telephone Network), at the moment, as the least expensive and most widespread, even in peripheral areas. Very often only this network can easily reach the user at home and chronically ill patients, such as those with CRF, very often need it for home care assistance. Moreover, the inclusion of services (e.g. video) using higher bandwidth, for example a real-time transmission of high-quality images, is envisaged only for some L.C.C. . The home peritoneal dialysis patient can forward essential treatment data through a suitably programmed Smart-phone. Artificial kidneys and other biomedical equipment connected to the patient, either at his/her home, in a Limited Care Centre or at hospital, can be universally interfaced with a specific "adaptor". There is, at present, a lack of compatibility in artificial kidney communication interfaces mainly due to the use of proprietary protocols.

Until there is standardisation, an adequate adaptation providing a format and codification conversion to unify clinical data relevant for health care purposes can already be adopted.

The presence of several types of Remote Centres (Limited Care Centres, Home haemodialysis and peritoneal dialysis), with diversified needs and requests, all referring to the same Service Centre (S.C.) is emphasised. It should also be noted that the possibility of dialogue with other nephrology department's Service Centres (n) is also considered. In this way an exchange of information between different national and international hospitals would be facilitated. This kind of dialogue is useful as it would provide data re-processing and recovery on a larger scale (regional, national or international). Practical examples of data recovery from other Hospital Centres would be the request for information from the "parent" centre regarding dialysis sessions carried out elsewhere by a patient whilst on holiday or also useful data to be processed for different national or international records (e.g. E.D.T.A.[1] register) for chronic uraemic patients.

3. The TELEDIAL subsystem for patients undergoing peritoneal dialysis

The rapid growth of peritoneal dialysis is due both to its lower cost and to the fact that, in most cases, it can be carried out directly by the patient at home. This technique can therefore be particularly useful in those nations where transplantation is widely available and dialysis is considered a temporary treatment whilst awaiting early grafting. On the other hand, this methodology can have application also in third world nations where it might be the only feasible technique: furthermore the long distances between hospitals and patients, together with low costs, justify the use of telemedicine systems for better management and follow-up of the patients. About 80% of peritoneal dialysis patients, at least in Italy, employ C.A.P.D. and for this reason the sub-system supporting this manual technique was considered first.

A Service Centre developed on a UNIX workstation supporting the tele-haemodialysis was already developed but, to reduce costs for small/medium configurations, it was decided to implement it also on a PC/Windows platform. For the remote domiciliary platform, a programmable smart-phone (fig. 2) was selected for several reasons: it is easier to use compared with a PC and it can replace the "normal" phone at the patient's home as well as being cheaper. Its limited performance, comparable with those of a PC-XT, are nonetheless sufficient for our purposes: moreover, the presence of a PCMCIA slot, a thermal printer, a chipcard reader and a serial interface, provide for further developments.

The enclosed figures show some examples of the implemented user interface: figure 3 is (on the smart-phone platform) an input card for the patient, while figures 4 and 5 show (on the hospital S.C.) a dialog box of the communication/teleprogramming application and a data base form to handle the received clinical data, respectively.

3.1 Offered services

Below is a short description of the currently implemented services in TELEDIAL, with new ones planned for future releases.

1. Automatic forwarding of patient clinical data - The service provides, at a patient's home, a simple method of data entry (the same data now found on paper in the "monitoring card") with the facility to forward them in an electronic format, by telephone, to the referral hospital for integration into a computerized clinical record. This allows a timely check of the patient's state of health and avoids the need for error prone manual transcription of data. Up to now, the

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[1] *European Dialysis and Transplantation Association*

information is available to the physician only after the monthly checkup with transfer to computer can even later, after manual insertion in a clinical chart. With the TELEDIAL system the data are locally inserted by the patient after every dialysis, directly in electronic format, and the connection with the S.C. can be programmed with an appropriate time schedule, such as daily. Depending on the configuration, the call can be initiated either by the patient or by the hospital S.C., allowing selection of preferred working options.

*2. **Teleprogramming of the remote domiciliary platform*** - This service allows modification, even radically, of both the patient/user interface and the behavior of the smart-phone. For example, the number of input cards for a daily dialysis can be set, and also the default values for type of dialysis solutions and quantities, drugs etc.. . The list of possible accidents and symptoms can also be remotely updated.

*3. **Mailing*** - Mail can be sent by both the patient and the physician including mail shots calling patients for a checkup. The next time each patient uses the smart-phone, he will be prompted to read the new mail: a confirmation of his reading will be sent back, together with the session clinical data, during the next connection with the S.C. .

*4. **"Privacy", "security" and power failure recovery*** - Protocols using in-band control messages have been implemented to provide both confidentiality and data integrity/availability. Access security, continuous and correct reception is assured and also all information and programmed calls are fully recoverable after power failure.

*5. **Multiuser remote platform*** - Several patients can use the same smart-phone. This additional functionality can be useful when the system is installed in a nursing-home or when several patients live together such as in cases of familial hereditary renal disease.

*6. **Multiconnection Service Centre*** - The S.C. can handle simultaneous connections and have an unified management of different possible remote/local links. In this way several simultaneous calls, depending on the available telephone inputs, can thus be handled to interface even large number of patients quickly.

4. Conclusions

A teledialysis system can offer a variety of services allowing an integrated and consistent management of nephropathic patients, independently from the location where dialysis takes place, the type of treatment adopted and the models of biomedical equipment used. Current commercial systems reflect only a small part of the potentialities.

The need to use telematic systems capable of "dialogue" with the outside world is clear to eliminate the risk of creating isolated centres. These systems must interact with each other easily in order to support increasingly complex configurations, new future services and integration with other health care information systems. Use of standards based on existing ones at international level regarding both communication and health care is essential.

The implemented prototype can be integrated in a more complete system environment. The use of a smart-phone at the patient side has allowed the realisation of a user-friendly interface and also a reduction of costs. The provided services allow a better follow-up of these chronic patients, enabling them to be in touch with the physician, even on a daily basis. The ongoing tests in a real environment will facilitate a better alignment to the physicians' and patients' needs and evaluation of this telemedicine system, including the economic dimension. This system can be extended readily to support other dialysis methodologies, for example interfacing the smart-phone to a "cycler" through its serial interface or using a PC as a remote platform, if heavy elaboration is needed: in fact, the SW that realise the S.C. can be configured also as a remote base platform. This is a generic system since other chronic patients (asthmatics, diabetics, etc.) and diseases could also take advantage of it, appropriately adapted to the specific requirements.

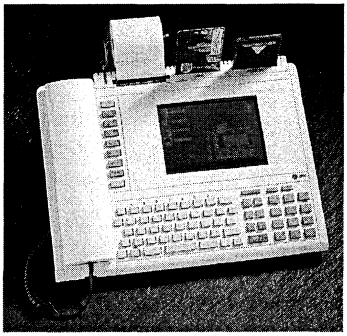

Fig. 2 - Smart-phone used as domiciliary remote platform

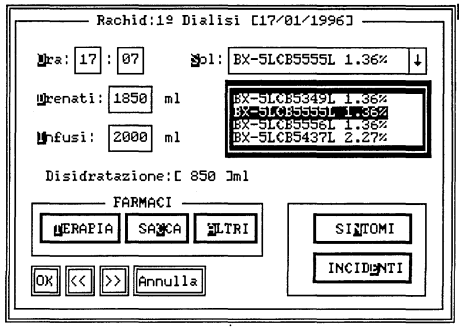

Fig. 3 - Example of user interface on the remote Smart-phone

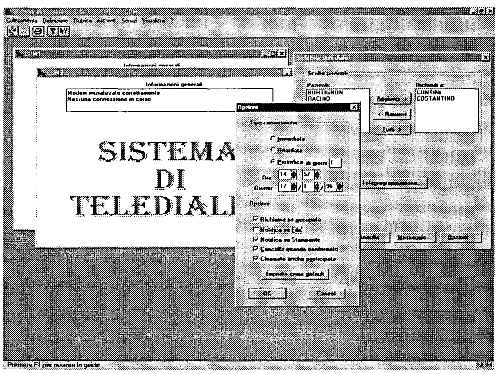

Fig. 4 - Example of user interface in the communication/teleprogramming application (S.C.)

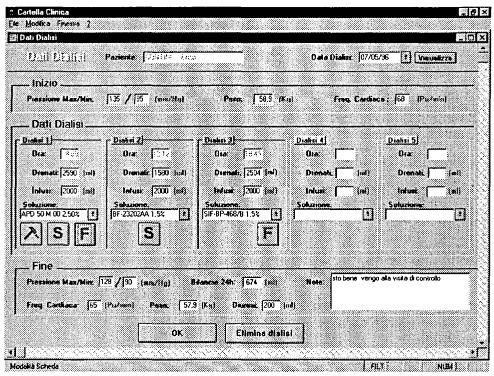

Fig. 5 - Example of data base form on the S.C.

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