Telematics Service for Home and Satellite Hemodialysis

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Home hemodialysis (HD) for the treatment of end-stage renal disease was first implemented about 30 years ago. In this paper the application of telematics monitoring services for supporting patients who need home HD or satellite HD is described.

Two modified HD machines were located in two renal units, and a central control station (CCS, UNIX workstation with multimedia PC terminal) was located in another room of the hospital. Bidirectional communication between the modified HD machines and the CCS was managed using ISDN (Integrated Services Digital Network) links. Nine patients had 150 HD sessions performed using these HD machines over a period of 5 months. This system, called the HOMER-D system, provided on-line, remote supervision of the HD machine-related functions and the clinical condition of the patients through measurement of blood pressure, pulse rate, PO_2 (pulse oxymetry), and ECG from the CCS. Any disturbances in the functioning of the HD machines were both visible and audible in the CCS, and the observer could give teleconsultation to the renal unit staff. No major dialysis-associated complications were observed; all data and alarms were transmitted correctly; and patients received adequate HD treatment.

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Key words

Telematics application, telemonitoring, ISDN

Introduction

Hemodialysis (HD) is one of the available treatments for chronic, irreversible renal failure. Previously, a high percentage of uremic patients were treated by home HD. However, today the proportion of patients treated by home HD is very low, despite the reports that this modality of treatment has lower mortality and offers better quality of life [1–3].

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Today's technical advances encourage the expansion of home HD. Telemedicine is a new development and covers medical activities including treatment and education [4–7]. The goal of this research is to marry home HD with telematic monitoring services for supporting uremic patients who need home or satellite HD treatment.

Material and methods

Two hemodialysis machines (HDM), TN-401 (ERGO S.A., Athens, Greece), were installed in the renal units of the participating hospitals. These machines were modified so that they could cope with the bidirectional communication demands and were connected using a network card and a router to the ISDN (Integrated Services Digital Network) line established for the project. A physiological parameters device, which transmits the patient's physiological data values [noninvasive blood pressure, PO_2 (pulse oxymetry), ECG, heart rate], was connected to the machines through a serial RS 232 interface and a data switch. A central control station (CCS), responsible for handling the data communication and medical database, and a multimedia terminal unit (MTU), which constitutes the graphics user interface of the system for monitoring and supervision of patients, were installed in a room separate from the renal unit and connected with a second ISDN line. The design of the system, called the HOMER-D system, is illustrated in Fig. 1.

After installation of the equipment a series of initial tests (HDM tests, telematic system tests) took place to ensure correct functioning, including some demonstration sessions for each machine. The demonstration sessions were a complete simulation of actual sessions without a patient being connected. After the initial tests were successfully completed, the actual clinical trials commenced. A total of 9 patients were selected for the clinical trials; all gave informed consent. These patients underwent 150 HD sessions over a period of 5 months in the two validation hospitals according to the following methodology: machine-related parameters (air in blood, bicarbonate conductivity, arterial and venous pressures, etc.) were continuously monitored by the CCS and displayed on the MTU's screen. Whenever the machine set off its alarm, it was automatically detected by the CCS, and a corresponding visual and audible indication on the MTU informed the medical staff of the type of alarm and reaction taken by the

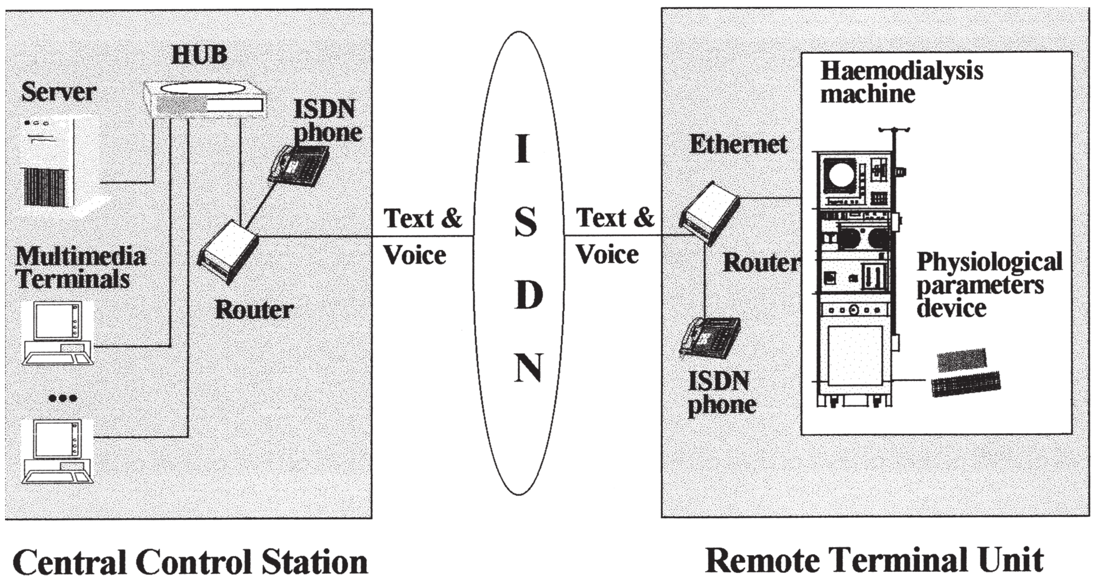

FIGURE 1 Design of the HOMER-D system. ISDN (Integrated Services Digital Network) lines enable bidirectional communication between the remote terminal unit at the patient's site and the central control station at the hospital.

HDM. The CCS sent a consultative message to the HDM's screen if the alarm persisted for a predetermined time period.

Patient-related parameters (noninvasive blood pressure, pulse rate, PO_2, ECG) could be checked whenever the supervising physician deemed necessary. When the blood pressure and pulse rate values exceeded some predetermined limits (specific for each patient), the system visually informed the supervising staff, who could, in turn, send a consultative message to the HDM's screen. Every hour during the HD session, the user verified the secure and safe transmission of data from the HDM to the MTU screen by checking the corresponding values. Whenever an error occurred (breach of communication, mechanical failure of machine components, etc.), it was logged on the relevant data sheet and handled afterward by the system's developers.

During the clinical trials, we performed a series of artificially provoked actions and alarms to test system performance under true clinical operating conditions. These actions included interruption of dialysate flow, clamping of blood lines, air bubble detector check, water supply failure, and electrical failure. All these actions were performed by the medical staff in the presence of the technician, to ensure complete patient safety and to evaluate the system's responses.

The adequacy of patients' HD was checked occasionally by determining Kt/V values, which were recorded with clinical laboratory measurements in the patient record.

Results

During the in-hospital clinical trials, no major, life-threatening dialysis-related complications were recorded. All disturbances of HDM functions were similar to the ones encountered during a normal HD session and were visible and audible to the CCS. All parameters were properly transmitted and recorded, and the observer could easily provide teleconsultation to the renal staff. During two HD sessions, the machines showed a technical problem and patients were transferred to other machines. The values of patients' physiological parameters were transmitted correctly to the CCS, and occasionally they were simultaneously verified by the nursing staff using external measurements. There was only one clinically significant hypotension event, and all warnings and alarms regarding blood pressure were due to excessive interdialytic weight gain. Eleven alarms indicating significant changes in heart rate were also recorded. Furthermore, patients had adequate HD treatment (Kt/V between 1.2 and 1.6). Table I shows the values of patients' blood pressure and ultrafiltration measured during the study. Table II presents a summary of all warnings and alarms that were encountered during the 150 sessions in both machine-related and physiological parameters, as well as communication errors.

Discussion

Home HD for the regular treatment of renal failure has been available since 1964. Twenty years ago, a high proportion of uremic patients were treated by home HD. However, the use of this modality of treatment has declined progressively, and now a low percentage of patients are treated by this form of HD. The main factors that negatively affected the development of home HD were the rapid proliferation of renal units and the appearance of continuous ambulatory peritoneal dialysis. The results of the current research support the suggestion that home HD might give better medical rehabilitation and more

TABLE I Clinical values of UF removed and blood pressure for each patient for a total of 150 sessions

Parameter	*Patient 1*	*Patient 2*	*Patient 3*	*Patient 4*	*Patient 5*	*Patient 6*	*Patient 7*	*Patient 8*	*Patient 9*
UF removed	2.3±0.5	3.8±0.9	2.8±0.7	3.6±0.7	2.4±0.7	3.1±0.5	3.1±0.6	2.8±0.4	2.7±0.4
SP Pre-HD	142±12	182±16	139±13	156±19	117±8	147±16	153±13	154±12	147±7
SP Post-HD	121±5	159±10	140±5	128±15	125±5	108±15	135±13	144±18	141±16
Maximum SP	170	210	165	190	130	180	180	180	160
Minimum SP	100	128	120	90	100	80	100	100	90
DP Pre-HD	80±5	97±11	83±8	87±8	76±6	86±5	81±7	82±7	81±4
DP Post-HD	75±2	80±7	84±8	76±5	82±4	69±8	77±4	77±5	77±5
Maximum DP	98	117	110	100	90	90	90	100	90
Minimum DP	66	60	70	60	60	60	60	60	60

UF = ultrafiltration; SP = systolic pressure; DP = diastolic pressure.

TABLE II Total number and type of alarms and warnings from hemodialysis machine to central control station during 150 sessions in 9 patients

Type of alarm/warning	*Occurrences*
Air in the blood	52
Blood leak	1
Total conductivity	58
Bicarbonate conductivity	31
Venous pressure	45
Arterial pressure	21
Temperature	2
Wrong ultrafiltration	1
Wrong dialysate flow	5
Backfiltration	0
Low water level	3
RTU fails to connect	6
No available MTU	0
Communication interrupted	15
Systolic pressure	17
Diastolic pressure	19
Pulse rate	11

RTU = remote terminal unit; MTU = multimedia terminal unit.

independence, and that it is the optimal treatment for patients who can do this. Moreover, in home HD the patient selects the day, the time, the frequency, and the duration of the HD session.

In order to do the treatment safely, the equipment must be fail-safe because home HD is often done overnight. Safe, user-friendly equipment and effective education enable patients and relatives to carry out this complex treatment. Telematics monitoring provides additional security measures and immediate access to professional advice.

Therefore, the goal of the current research is to find a system for home HD acceptable in terms of efficiency, effectiveness, helpfulness, control, and ease of learning. Recently, continuous monitoring at a nocturnal HD hospital center using a modem of patients who dialyze 6 – 7 nights per week for 8 – 10 hours during sleep has been reported. Later, the same authors monitored patients over an established remote connection over the Internet [1,4].

The aim of our project was to marry HD with telematics monitoring services to support uremic patients who need home or satellite HD treatment. Telemedicine is likely to play an increasing role in future health care. It would facilitate the decentralization of health care delivery. The advantage of telemedicine is the fast, two-way electronic network, which allows interactive communication between doctors and patients. In our study the interconnection between HD machines and a CCS was achieved using the ISDN line.

The aims of this innovative telematics monitoring service are twofold: first, to assist medical/nursing staff at the CCS to monitor on-line several HD machine-related parameters and medical parameters of patients during the HD sessions and to assess patients' conditions; and second, to assist patients and their partners at home in receiving critical advice from the CCS medical/nursing staff regarding normal and alarm conditions during HD sessions [5–7].

During our clinical trials, the communication and information were adequate, the sound and vision satisfactory, and the arrangements successful. Hemodialysis sessions were regular without unusual symptoms, and the treatment was adequate. We think that this system provides uremic patients on home HD with "supervised autonomy." With this system, HD machine-related parameters (air in blood, dialysate conductivity, arterial and venous line pressure, etc.) and medical parameters (blood pressure, PO_2, pulse rate, ECG) can be transmitted to the CCS, and consultative messages from the CCS can be received by patients and their partners at home. Our preliminary results seem promising for the success of the system. However, according to the research project's schedule, more clinical trials will take place in two other European hospitals and then in patients' homes.

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