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Treatment Assistance and Prioritization of Referrals of Renal Impairment Patients In Rural Areas of Eastern India Using Decision Support Telemedicine System

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Abstract

In this paper a telemedicine system with some decision making capabilities has been developed to provide treatment assistance to renal impaired patients in rural areas of eastern India. The primary objective is to estimate the severity of the renal condition of the patients in rural areas, accordingly prioritize their referrals and exchange their relevant information on the basis of priority to seek medical advise from the nephrologists of the tertiary center via the communication network of the telemedicine framework. The concept has been implemented in a clinical trial of 50 patients. The clinical trial of the patients has been carried out for six months (June-Nov. 2007). Using the prioritization algorithm proposed here, 27 out of 50 patients' information have been sent in the first month to the tertiary center for quick follow up. Out of the remaining 23 patients, only 5 patients were given follow up dates at the tertiary center and the remaining 18 patients were given medical advice through the telemedicine framework thus reducing the patient load of the tertiary center by almost 40%. The decision of the prioritization algorithm has been matched with that of the physicians. The results indicate that the proposed telemedicine system has the potential to work as an efficient tool to provide better treatment for renal impaired patients in rural areas by decreasing the work load of the nephrologist at the tertiary centers and also sparing the patients of the burden to travel long distances frequently.

I. INTRODUCTION

Chronic renal failure leading to End Stage Renal disease (ESRD) has become rampant in India [1]. Diabetes and hypertension are the common causes for renal failure and such population in India increasing in a geometric progression, there has been an unexpected rise of such cases. There is no therapeutic cure for renal failure. Dietary adjustment- control of hypertension and diabetes are the cornerstones by which we can delay the progression of the disease. ESRD calls for some form of renal replacement therapy (RRT) i.e. haemodialysis, peritoneal dialysis or transplant, all of this is usually available in a large metropolis.

As the Indian healthcare system is a three tier system, starting from primary health care centers in the villages, then the district hospitals and then the teaching and multispeciality hospitals in large cities, specialist consultation is available in district and medical colleges and dialysis facilities in only medical colleges and superspecialty hospitals. It has been seen from survey that results percentage of qualified consulting doctors practicing in urban and semi-urban areas are 75 and 23 respectively while in rural areas only 2% get this service, while the majority of the patients come from rural areas. The number of hospital beds/1000 people is 2.2 in urban and 0.19 in rural areas. Also the cost of dialysis per week even at the cheapest of private centers is Rs.6400 per month and in Government Hospitals where people pay for disposables it is about Rs3000 per month. The per capita income of an Indian varies from Rs.1000-Rs1500 per month. In the backdrop of this situation, the deployment of telemedicine can offer one of the best solutions for providing the proper service to the really needy people suffering from renal dysfunction. It will be very useful both for retarding the progress of the disease by early dietary modification and drug usage to controlling diabetes and hypertension. It will also lessen the load of patients at the nephrology department of tertiary care centers. Thus, the present work deals with the development of a decision making telemedicine system for the above-mentioned purpose.

There are some reports on some in-situ diagnostic support systems such as detection of arterial condition from Doppler ultrasonography [2], use of the computer to assist dermatological diagnosis in general practice [3], predicting active pulmonary tuberculosis using an artificial network [4], detection of interstitial opacities in chest radiographs [5] and others. Based on the output of these systems. The patients can contact the physician directly or through some teleconsultation system if developed in the locality. There are some works on the effectiveness of interventions using information and communication technologies (ICTs) for managing and controlling chronic diseases [6,7]. With the help of this method 950 clinical trials were identified and 56. Telemedicine framework for a collaborative pacemaker follow up has also been developed and reported[8]. But most of these diagnostic systems require computers for operation which require connectivity through land lines or mobile communication facilities to operate. But in remote rural areas of Eastern India, regular power supply is a problem. In fact, India accounts for a third of the world's population and about 40% of those without access to modern electricity [9]. There are some industries, which have already taken the initiative to develop telemedicine system in eastern rural India. For example, WEBEL (West Bengal Electronics) ECS (Electronics and Communication Software Ltd.) have implemented two telemedicine projects in Eastern India. The first one involves the transmission of data, image, graphics, voice and video over a narrow bandwidth. The second one involves linking two tertiary centers with four secondary centers. Through this framework, the cases of Radiology, Cardiology, Medicine and Haematology have been covered [10]. There is another organization named CDAC (Center for development of Advanced Computing) which has developed an interactive Web Interface for acquiring data, diagnostic assistance, user discovery and connectivity, sending and receiving offline data and other applications [11]. However there are no communication networks developed between the primary health care centers and higher centers. Mobile networks are yet to be developed in the vicinity of the primary health care center in rural areas. Also, the primary health care centers are at least located 5km from the secondary center, thus traveling this distance every day for a health check up specially for critical diseases like renal failure is not feasible. Since, the mode of transport is inadequate in these areas and the income level for most of the population in the rural areas do not allow them to support having a personal vehicle, it is necessary to develop a customized telemedicine system at the primary health care center. Visualizing the Indian telehealth need and it's present status, a telemedicine framework for renal impairment patients in the rural areas of Eastern India has been proposed. It uses a portable battery operated microcontroller kit with a wireless interfacing unit to connect the primary health care center to the nearest secondary center from where further exchange of information can occur with the tertiary center through the already established network.

Decision making telemedicine system

We propose a telemedicine framework for treatment assistance to renal impairment patients. The primary objectives are: (a) prioritization of the referrals of patients after estimating the severity of the renal condition and (b) send the data of the patients according to a priority to seek medical advise from the nephrologists of the tertiary center. The basic procedural steps required for implementing the concepts (shown in Fig.1) are:

i) Patient selection and prioritization

Patients suffering from renal problems would be selected by the physician at the primary health care center based on inclusion criteria. Thus, the data of these patients are to be prioritized by the decision making algorithm before sending them to the tertiary centers.

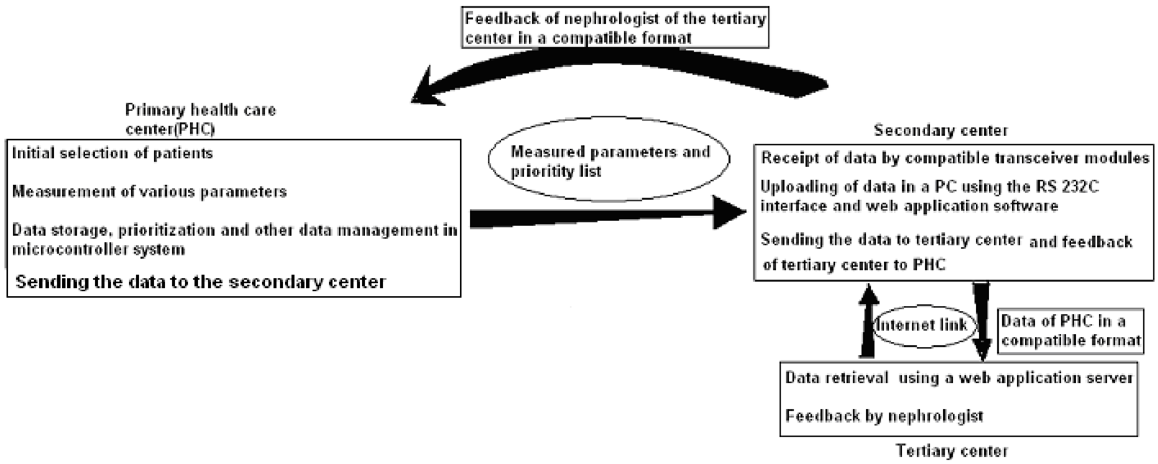


Figure 1.
Basic procedural steps of the telemedicine framework

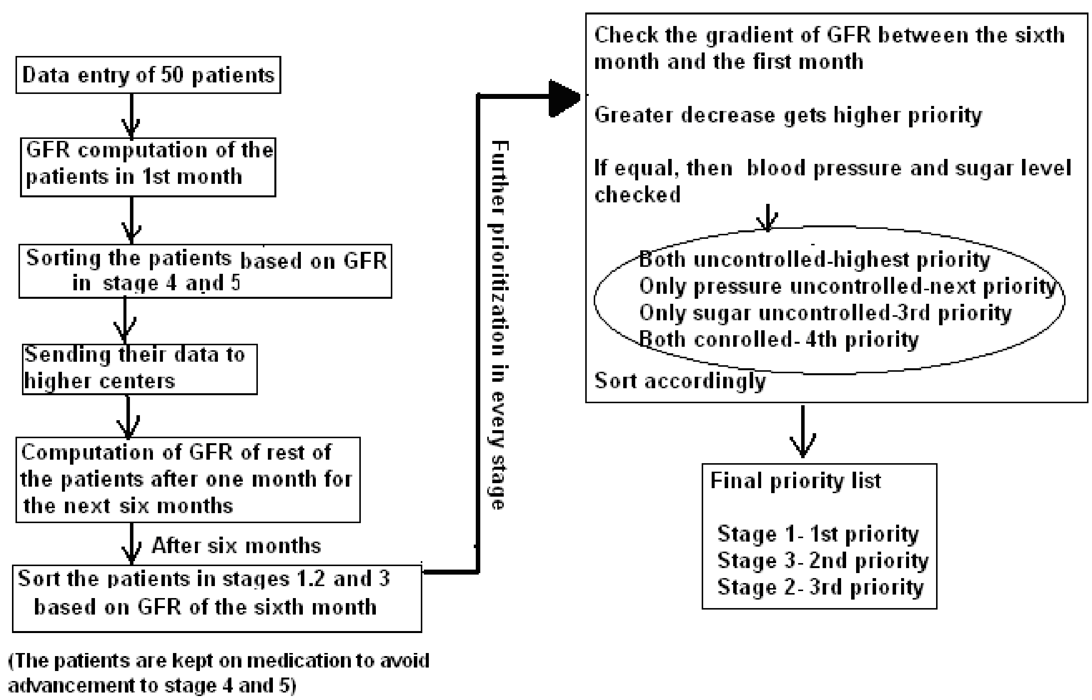


Figure 2.
Flow diagram of the prioritization algorithm

ii) Data storage and processing
For prioritizing the data of the patients the information would be stored in the system in appropriate memory locations. After prioritization, the patient's data are grouped accordingly so that they can be transmitted to the tertiary center in the proper manner according to their priority.

iii) Data transmission
After the stored data in the microcontroller at the primary health care center have been processed, they are sent by the telemedicine framework established up for this purpose. Data transmission is a two way process. From the primary health care center, processed data after prioritization are sent to the tertiary care center and the advise along with necessary information from the tertiary care center are transmitted to the primary health care center. Secondary centers act as an interface for data transfer between primary health care center and tertiary center.

iv) Feedback to patients
The feedback from the tertiary center in the form of advise is observed by the operator in the primary health care center in the microcontroller kit and is relayed to the patients. This process has been implemented in a clinical trial of 50 patients for a period of six months.

II. METHODS

Patient selection at the primary health care center:

The steps for selecting the patients were as follows:

i) Initially the physician selected 55 patients from his clinic with the presence of diabetes and hypertension and the risk of renal failure as diagnosed by him after their first visit.

ii) These patients are advised by the physician to carry out the plasma creatinine test. The glomerular filtration rate (GFR) is computed manually according to the Cockcroft Gault equation[12] given in equation 1 by a paramedical staff at the primary health care center immediately within a day.
GFR = ((140-AGE) X WEIGHT)/(72 X CREATININE) (1)

iii) The patients with GFR greater than 90 are advised to perform the proteinuria test by the dipstick method in the primary health care center. If proteinuria is present, the patient is referred to tertiary center for evaluation of adult proteinuria with renal biopsy and other sophisticated investigations to rule out urinary tract infection and paraproteinamias. In patients where proteinuria is absent, microalbuminuria is tested from a secondary center laboratory. If positive, they are included in the system and if negative, they do not match the inclusion criteria. To complete this process, about a week time is required since the patients have to travel to the higher level centers.

iv) In this way, out of 55 patients, 50 patients were found to be suitable for prioritization.. Hence on basis of above discussion, the inclusion criteria may be summarized as:

- Diabetic and hypertensive subjects with creatinine clearance <90
- Diabetic and hypertensive subjects with creatinine clearance >90 with associated microalbuminuria/proteinuria

The exclusion criteria can be summarized as follows:

- Non-diabetic, non hypertensive patients with impaired creatinine clearance
- Acute renal failure due to obvious causes like snakebite etc.

Patient prioritization algorithm at the primary health care center

For the selected patients, prioritization is first done by calculating the GFR which is indicative of the creatinine clearance using the Cockcroft Gault Formula [12] given in equation1.

Plasma creatinine is done in the laboratory of the primary health care center. Depending on the values of the GFR, the patients are grouped by the system in the following categories [13]:

GFR >90 ------ stage 1
>60--------stage 2
>30--------stage 3
>15--------stage 4
<15--------stage 5

Those with creatinine clearance less than 30(corresponding to chronic kidney disease(CKD) stage 4 and 5) are promptly referred to a tertiary care center with nephrology facilities as they will require renal replacement

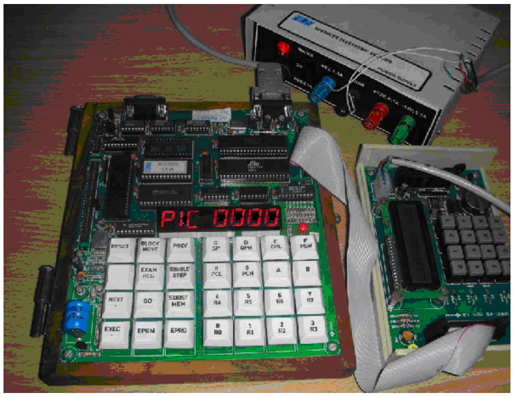
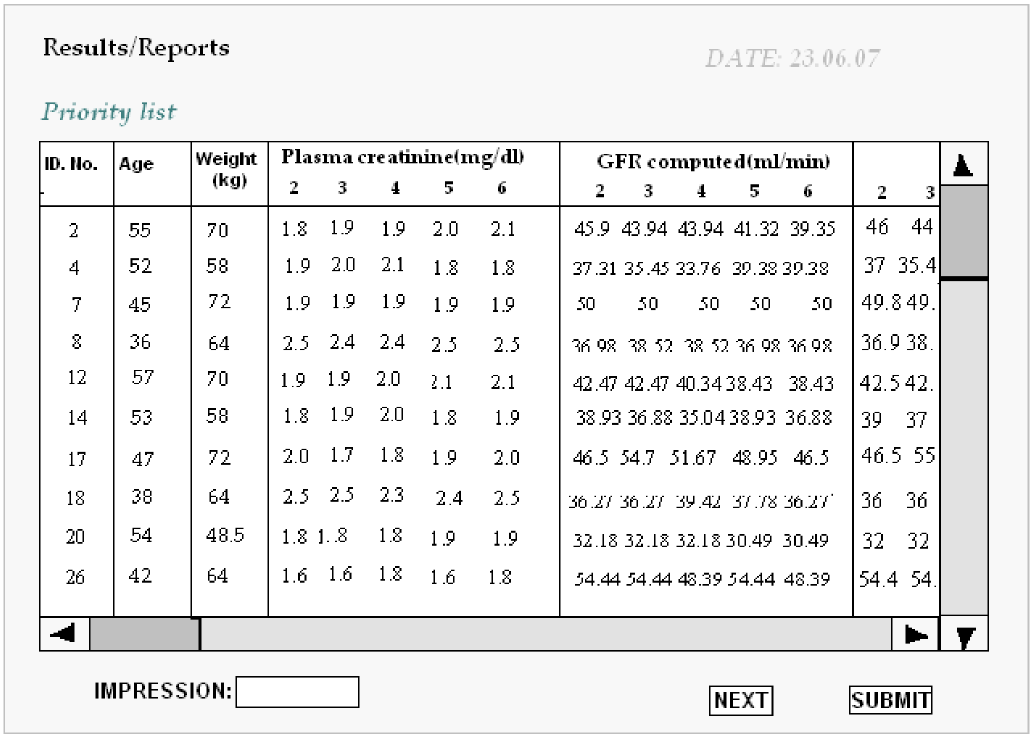


Figure 3.
Picture of the microcontroller kit



Results/Reports

DATE: 23.06.07

Priority list

ID. No.	Age	Weight (kg)	Plasma creatinine(mg/dl)					GFR computed(ml/min)						
			2	3	4	5	6	2	3	4	5	6	2	3
2	55	70	1.8	1.9	1.9	2.0	2.1	45.9	43.94	43.94	41.32	39.35	46	44
4	52	58	1.9	2.0	2.1	1.8	1.8	37.31	35.45	33.76	39.38	39.38	37	35.4
7	45	72	1.9	1.9	1.9	1.9	1.9	50	50	50	50	50	49.8	49.
8	36	64	2.5	2.4	2.4	2.5	2.5	36.98	38.52	38.52	36.98	36.98	36.9	38.
12	57	70	1.9	1.9	2.0	2.1	2.1	42.47	42.47	40.34	38.43	38.43	42.5	42.
14	53	58	1.8	1.9	2.0	1.8	1.9	38.93	36.88	35.04	38.93	36.88	39	37
17	47	72	2.0	1.7	1.8	1.9	2.0	46.5	54.7	51.67	48.95	46.5	46.5	55
18	38	64	2.5	2.5	2.3	2.4	2.5	36.27	36.27	39.42	37.78	36.27	36	36
20	54	48.5	1.8	1..8	1.8	1.9	1.9	32.18	32.18	32.18	30.49	30.49	32	32
26	42	64	1.6	1.6	1.8	1.6	1.8	54.44	54.44	48.39	54.44	48.39	54.4	54.

IMPRESSION:

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Figure 4.
Snapshot of the screen showing the data of the patients at tertiary center

therapy within a short period of time. The remaining patients with creatinine clearance greater than 30 i.e. CKD stage 3 , 2 and 1 are enlisted for serial follow up upto 6 months. After six months, the prioritization results of the remaining patients are obtained. Stage 1 gets the highest priority as proper angiotensin convertin enzyme(ACE) inhibitor ± angiotensin receptor blocker(ARB) therapy can cause a potential reversibility and thus prevent CKD in such patients. Stage 3 and stage 2 then receive priority in that order because stage 3 is more likely to progress to ESRD than stage 2.

For patients falling under the same stage, finer prioritization based on gradient of GFR, blood pressure and status of diabetes are done according to convention [13]. The gradient in GFR is computed by the difference in GFR values between the first and the sixth month. The patient whose GFR has reduced more gets the higher priority over the others in that stage. If the gradient is equal for more than one patient under the same stage, then prioritization is carried out on the basis of the status of blood sugar and hypertension. A patient with the presence of both uncontrolled blood sugar and hypertension gets the highest priority. Patients with uncontrolled value of blood pressure get the next priority followed by uncontrolled value of blood sugar and patients with both of these under control get the lowest priority. The flow diagram for the algorithm is shown in Fig.2.

Data storage and processing at the primary health care center

The microcontroller based telemedicine system is operated by a non-medical staff in the primary health care center. Three programs in C have been downloaded in the ROM of the PIC16F877A microncontroller interfaced with an additional numerical keyboard with alphanumeric display and a wireless transceiver system TCM3-4DIO[14] to exchange information with the higher centers. The picture of the system is shown in Fig.3. The front-end program primarily carries out the data entry task . The different parameters of a patient namely identification number (ID), month of visit, age, weight, GFR and plasma creatinine are entered into the specific locations of (ROM) of the microcontroller chip by the non-medical staff onn a monthly basis. The GFR value from the laboratory is required only to validate the results of the system with the physician's decision. During the entry of data, if similar data are entered twice, an alarm CHK is flashed on the LED screen and the data can be reentered. After data entry is complete, the front-end program automatically computes the value of GFR according to equation1. After calculation, the data of GFR of each patient are stored in the corresponding memory locations. For calculating the GFR values, some computer arithmetic algorithms had to be applied since the microcontroller did not support floating-point operations. The algorithm is primarily multiplication of all the entered values by 10 to remove the decimal followed by division using repetitive subtraction method [15].

After the entry in the first month, the data of all the patients who fall in stage 4 and 5 are sorted and grouped in a particular location and immediately sent via the wireless link to the higher center. The rest of the patients are advised to report in the primary health care center after one month with the results of the test---plasma creatinine, blood sugar, hypertension and GFR. If the non-medical staff finds that the diabetes and hypertension are not under control, then he instructs the patient to consult the physician else the patients do not need to consult a physician from their second visit.Targets were set up to keep their diabetes and hypertension in control. Contraindicated drug lists were prepared and handed over. Appropriate drug lists were prescribed to these patients to keep systolic blood pressure <130mm of Hg and diastolic blood pressure <85 mm of Hg, fasting blood sugar <110gm/dl and post prandial blood sugar <150gm/dl.This process continues for six months. In the sixth month along with the other data, the hypertension and diabetes status of patients are entered into the system corresponding to the respective memory locations for the patients. For the sake of programming, the status of blood pressure and sugar are entered as 00, 01, 02, 03 corresponding to controlled blood sugar and hypertension, uncontrolled blood sugar only, uncontrolled hypertension only and both uncontrolled respectively. At the end of six months, the back end program is executed where the prioritization of the remaining patients is done according to the algorithm discussed in Fig.2. After prioritization, the patient's data are grouped in various stages with the decreasing order of priority. These grouped data are sent to the higher center for the advise of the nephrologists.

For transmission and reception of data in the primay health care center through the microcontroller, a third program is required to be downloaded in the ROM. This program assigns functionalities to the specific keys in the keyboard interface with the microcontroller . For transmission of the patients' data, a key marked as 'SEND' has been designated, pressing which the transmission process starts. Similar to signal the receipt of the data from the higher center. An LED is programmed to glow. The operator then observes the data sent from the tertiary center in the specific memory locations or in an alphanumeric display which have been programmed accordingly depending on the requirements.

Data transmission and management in the telemedicine frame work

The transmission of data is a two way process. For forward transmission of the prioritized patient data from the primary health care center to the higher center, the wireless link of the transceiver TCM3-4DIO interfaced with the battery operated microcontroller. It can transmit data in a frequency of around 173MHz for a range of 5km. With this range, the data are received by a similar microcontroller system in the secondary center, which is located within this radius. The transceiver module of the microcontroller handles all necessary related protocol to ensure error free and uninterrupted data transfer over the communication link between two modules. All data transfers between a pair of transceivers are fully acknowledged, thus preventing the loss of data. Error checking methods are used on the data packets to ensure the validity of the received data at the remote end. An LED is made to glow in the microcontroller kit placed in the secondary center to signal the receipt of data from the primary health care center.

At the secondary center, the data from the microcontroller are uploaded into the PC in a file by a RS-232 interface. The contents of the file are then uploaded in the web application server Mercury along with a database system developed by CDAC for telemedicine purposes[11]. The uploaded data are sent by the transmission link setup between the secondary center and the tertiary center which is a 512 Kbps leased line with WBSWAN (2 Mbps fiber optic link) of WEBEL[10].

The nephrologist at the tertiary center observes the data through the Mercury application server and sends his advise through the established link. At the secondary center, the advise is saved in a format compatible with the microcontroller in a file with the help of the database system of CDAC and are subsequently downloaded to the microcontroller kit which is sent to the primary health care center. At the secondary center, it is first checked whether there are any data to be forwarded from the primary health care center by checking the LED flash. If not, only then will the nephrologists advise be transferred to the primary health care center. This is done to avoid collision between the two-way transmission process.

Data Review and Clinical Evaluation

The nephrologist at the tertiary center observes the data with the help of the web application server and the database system developed by CDAC. The snapshot of the screen showing the data of the patients which is observed by the nephrologist is shown in Fig.4. The nephrologist observes the priority list of the patients, the blood pressure and sugar values and sends the follow-up dates, medicinal advise or diet charts as required. Also, for validation of the prioritization algorithm with the clinical evaluation, the nephrologist observes the GFR values of the patients obtained from the laboratory and mentions his clinical impressions. If he feels that the prioritization done by the system is correct, he sends 'OK' otherwise he sends the patient's ID number which deviates from the priority list as per clinical diagnosis. At the primary health care center, operator observes the follow up dates in the LED display of the microcontroller board and the diet charts, medical advise and physician's decision in the alphanumeric display of the interfaced keyboard.

III. RESULTS AND DISCUSSIONS

In the course of the clinical evaluation, a total of 50 patients has been selected. Table I shows the baseline data for the first month for 50 patients as obtained from the tests performed in the primary health care center. Table 2 shows the computed values of GFR, the practical tested values of GFR and the stages for the first month for 50 patients. It is observed from tables 1 and 2 that 27 out of 50

Table 1
Baseline data for 50 patients

ID No.	Age(years)	Weight(kg)	Creatinine(mg/dl)
1	63	66	2.1
2	55	70	2.1
3	35	67	3.8
4	52	58	1.8
5	70	51	2.8
6	61	56	2.1
7	45	72	1.9
8	36	64	2.7
9	79	54	3.3
10	52	48.5	2.2
11	65	66	2.8
12	57	70	2.1
13	37	67	3.8
14	53	58	1.8
15	72	51	2.8
16	63	56	2.1
17	47	72	1.9
18	38	64	2.7
19	78	54	3.3
20	54	48.5	1.9
21	67	66	2.8
22	67	69	2.8
23	63	58	2.1
24	37	69	3.8
25	72	53	2.8
26	42	64	1.5
27	61	55	2.1
28	56	42	1.9
29	29	79	1.3
30	50	64	1.5
31	57	60	2.7
32	51	44	4.2
33	68	56	1.3
34	35	51	1.6
35	65	61	2.2
36	41	56	1.7
37	50	70	2.1
38	62	64	3.1
39	55	60	1.6
40	48	50	1.8
41	61	53	2.1
42	42	60	1.3
43	48	64	1.5
44	52	63	1.9
45	50	52	1.4
46	60	48	2.0
47	41	56	3.1
48	62	59	4.8
49	36	44.5	3.0
50	52	61.5	2.1

Table 2
GFR values and stages for 50 patients in the first month

ID No.	Stage	GFR computed(ml/min)	GFR from laboratory(ml/min)
1	4	25.1	25.0
2	3	39.35	39.3
3	4	27.7	27.6
4	3	39.38	39.5
5	4	17.6	17.6
6	4	29.1	29.0
7	3	50	49.9
8	3	34.24	33.9
9	5	12.9	12.7
10	4	26.9	26.7
11	4	24.7	24.8
12	3	38.43	38.5
13	4	25.3	25
14	3	38.93	39
15	4	17.1	17
16	4	28.7	28.6
17	3	48.95	49
18	3	33.58	33.8
19	5	14.2	14.1
20	3	30.49	30.6
21	4	24	24.1
22	4	24.98	25
23	4	29.54	29
24	4	26.2	26
25	4	18	18.2
26	3	58.07	58
27	4	28.73	28.7
28	4	25.78	25.7
29	1	93.68	93.6
30	3	53.33	53.3
31	4	25.61	25.6
32	5	12.95	12.9
33	3	43.07	43.7
34	3	46.48	46.4
35	4	28.88	28.9
36	3	45.29	45.3
37	3	41.67	41.7
38	4	22.35	22.3
39	3	44.27	44.7
40	3	35.49	35.5
41	4	27.69	27.7
42	2	62.8	62.8
43	3	54.52	54.5
44	3	43.24	43.4
45	3	46.43	46.4
46	4	26.67	26
47	4	24.84	24.8
48	5	13.32	13
49	4	21.43	21.4
50	3	35.79	35.8

Table 3
Data of patients from the 2nd to sixth month

ID No.	Plasma Creatinine(mg/dl) Months					GFR computed(ml/min) Months					GFR lab(ml/min) months					Stage	Blood pres-sure/sugar status(presence/absence)
	2	**3**	**4**	**5**	**6**	**2**	**3**	**4**	**5**	**6**	**2**	**3**	**4**	**5**	**6**		
2	1.8	1.9	1.9	2.0	2.1	45.9	43.94	43.94	41.32	39.35	46	44	44	41	39.3	3	00
4	1.9	2.0	2.1	1.8	1.8	37.31	35.45	33.76	39.38	39.38	37	35.4	34	39.4	39.5	3	00
7	1.9	1.9	1.9	1.9	1.9	50	50	50	50	50	49.8	49.9	49.7	49.8	49	3	00
8	2.5	2.4	2.4	2.5	2.5	36.98	38.52	38.52	36.98	36.98	36.9	38.5	38.5	36.9	37	3	00
12	1.9	1.9	2.0	2.1	2.1	42.47	42.47	40.34	38.43	38.43	42.5	42.5	40	38	38.5	3	00
14	1.8	1.9	2.0	1.8	1.9	38.93	36.88	35.04	38.93	36.88	39	37	35	39	37	3	00
17	2.0	1.7	1.8	1.9	2.0	46.5	54.7	51.67	48.95	46.5	46.5	55	51	48.9	46	3	00
18	2.5	2.5	2.3	2.4	2.5	36.27	36.27	39.42	37.78	36.27	36	36	39	38	36	3	01
20	1.8	1.8	1.8	1.9	1.9	32.18	32.18	32.18	30.49	30.49	32	32	32	30	30	3	00
26	1.6	1.6	1.8	1.6	1.8	54.44	54.44	48.39	54.44	48.39	54.4	54.4	48.3	54.4	48.3	3	00
29	1.5	1.8	1.9	2.0	2.5	81.19	67.66	64.1	60.89	48.71	81.2	67.6	64	60.8	48.7	1,2,3	01
30	1.5	1.5	1.5	1.5	1.5	53.33	53.33	53.33	53.33	53.33	53.3	53.3	53.3	53.3	53.3	3	02
33	1.4	1.2	1.2	1.2	1.2	40	46.67	46.67	46.67	46.67	40	46.6	46.7	46.7	46.7	3	00
34	1.7	1.85	1.8	1.9	2.0	43.74	40.2	41.31	39.14	37.18	43.7	40.2	41.3	39.2	37.2	3	00
36	1.9	1.8	1.9	1.9	2.0	40.53	42.78	40.53	40.53	38.5	40.5	42.8	40.5	40	38	3	00
37	2.1	2.1	2.2	2.1	2.1	41.67	41.67	39.77	41.67	41.67	41.7	41.7	39.8	41.7	41.7	3	00
39	1.6	1.9	2.0	2.0	1.8	44.27	37.27	35.42	35.42	39.35	44.7	37.7	35	35.4	39.3	3	00
40	2.0	2.1	2.1	2.0	1.8	31.94	30.41	30.41	31.94	35.49	31.9	30.4	30.4	31.9	35.5	3	00
42	1.3	1.3	1.3	1.3	1.3	62.8	62.8	62.8	62.8	62.8	62.8	62.8	62.8	62.8	62.8	2	03
43	1.4	1.5	1.5	1.4	1.5	58.41	54.52	54.52	58.41	54.52	58.4	54.5	54.5	58.4	54.5	3	00
44	2.1	2.2	2.4	2.1	2.2	39.27	37.48	34.36	39.27	37.48	39.3	37.5	34.4	39.3	37.5	3	01
45	1.5	1.5	1.4	1.5	1.6	43.33	43.33	46.43	43.33	40.63	43.3	43.3	46	43	40.5	3	00
47	3.0	2.6	2.6	2.5	2.5	25.67	29.62	29.62	29.62	30.8	25.7	29	29	29	31	4,3	00
50	1.8	1.9	2.0	2.0	2.0	41.76	39.56	37.58	37.58	37.58	41.7	39.6	37.6	37.6	37.6	3	00

Table 4
Priority list of patients

ID no. of patients according to priority	20, 47, 40, 18, 14, 8, 34, 44, 50, 12, 36, 39,2, 4, 45, 37, 17, 33, 26, 29, 7, 30, 43, 42

Table 5
Follow up dates of the patients in stage 4 and 5

ID No. of patients	Date of follow up/advise
9,32,48,19	5/6/07
15,5,25,49,38	9/6/07
21,11,47,22,1,13	16/6/07
31,28,24,46,10	23/6/07
41,3,16,27,35	30/6/07
6,23	7/7/07
49	No follow-up date, medicinal advise provided

Table 6
Follow-up dates of the patients in stage 1,2 and3

ID No.of patients	Follow up dates/decision
20	10/11/07
47	10/11/07
10	10/11/07
40	10/11/07
18,14,8,34,44,50,36,39,2,4,45,37,17,33,26,7,30,43,42	Refer to Secondary center
29	3/11/07

patients are in stages 4 and 5 and their data are immediately sent to the tertiary center through the wireless link of the microcontroller and the network of the telemedicine framework. From the next month, the data of the remaining patients are entered. This process continues up 6 months. Table 3 shows the data for the remaining patients from 2nd to 6th month (the weight has been found to be constant and hence it was not included in the table). The blood pressure/sugar level for these patients are entered only in the 6th month. This is because the blood pressure and sugar are measured every month by the non-medical operator. If there is an abnormality, patients are given diet chart by the physicians. The code for blood pressure/ sugar status has been explained in the previous section on data storage and processing. In table 3, 1st month corresponded to May 2007 and 6th month corresponded to October 2007. Table 4 shows the priority list of the rest of the patients as computed by microcontroller after six months. It is observed from table 3 that patients 39 and 3 have the same GFR value after six months. But there is a decrease in GFR for patient 2 unlike patient 39, thus patient 2 received higher priority over patient 39 following the criteria discussed in the previous section. The data of all these patients according to priority are sent to the nephrologists at the tertiary center at the end of sixth month.

Nephrologist's advise and follow-up schedule

The follow-up dates or advise suggested by the nephrologist for the patients in stage 4 whose data have been sent after the first month are shown in Table 5. The follow-up dates of the patients are provided for the months of June and July 2007. The nephrologist suggested the dates according to the increasing value of GFR. However, no date has been provided for patient 47. He has been referred back by the nephrologists with advise for medication and patient 47 was found to improve to stage 3 after six months, as seen in Table 3. The follow up dates and other decision as given by the nephrologists of the tertiary center for the rest of the patients after sixth month is shown in Table 6. It can be seen from table 6 that patient 29 is given an earlier date for follow up despite a higher value of GFR compared to others. This is because patient 29 had a progressively increasing value of GFR and ended up in stage 3 from stage 1. Out of the remaining 23 patients, only 5 patients were given follow up dates at the tertiary center and the rest 18 patients were referred to secondary center.

Validation with the physician's decision

To validate the prioritization done by the system with the nephrologist's decision, the operator sent all the data of the patients along with the GFR obtained from the laboratory via the wireless link to the three nephrologists at the tertiary health care center. The nephrologist's diagnosis was based on the GFR value obtained from a standard laboratory from a 24 hour urine and plasma creatinine value. Since the GFR value has been found to match well with the laboratory result, the nephrologist's decision tally closely with the system. However there was a deviation in the decision of patient number 29. Patient number 29 ended up in stage 3 from stage 1 of CKD and needed urgent referral to a nephrologist. Though the system did not give him the maximum weight for prioritization, the nephrologists prioritized him immediately after the stage 5 and 4 patients on the basis of clinical assessment and findings. For patient 29, his renal failure had progressed possibly from some form of glomerulonephritis because CKD did not progress so rapidly due to diabetes and hypertension. This patient was under control. Such patients did not fall under the purview of the system as it was not valid for renal dysfunction due to glomerulonephritis.

Discussions

In the telemedicine framework presented in this paper, the data of the patients (not in stage 4 and 5) were sent to the tertiary center at the end of six months after prioritization. The prioritization algorithm described here is valid for chronic renal failure patients due to diabetes and hypertension. Since the diabetes and hypertension amounted to 70% of the total number of renal failure patients, the proposed telemedicine system catered to majority of the critical patients and thus was very useful. Due to prioritization, the outpatient department load of the nephrologists was distributed evenly and those requiring attention received an earliest date. This improves the quality of treatment with the limited resources available.

Also prioritization was done after six months to avoid the occurrence of false indications of chronic renal failure which may unnecessarily increase the load of the nephrologists. Such false alarms may occur in our country since diarrhoeal disorder is very common, and values of urea and creatinine often change in a post diarrhoeal state due to pre-renal azotemia if fluid is not adequately replaced. The values of urea and creatinine can indicate stage 4 or 5 for the patient temporarily which is actually not due to the renal failure. Thus, if monthly analysies is done, there might be an unacceptable number of false positive indications of renal failure.

The nephrologist's impression is provided after observing the GFR value obtained from the laboratory which has been found to match with the GFR value computed. GFR value in the laboratory is obtained as [16]:

GFR= (Urinary creatinine X Urine flow/unit of time)/Plasma creatinine

Comparing this with the Cockcroft Gault equation 1, we observe that the two equations differ in the numerator. The numerator term in equation 1((140-age)X weight)/72 has been obtained by empirical fit of different categories of age and weight of a large number of patients with the GFR obtained from the laboratory[11], and thus were widely used where laboratory facilities were not available.

One general exception of our system was that the treatment of patients with renal dysfunction due to some form of nephritis not within it's purview. This is because cases would require personal intervention of the nephrologists(renal biopsy and others).Patient 29 was one such patient whose renal failure was from glomerulonephritis and hence could not be prioritized properly. Treatment for such patients are difficult to be done by any telemedicine facility.

In the proposed telemedicine system, data security is ensured by sending patient's data with identity numbers only without any names. Reliability is achieved by using radio transceivers ensuring that all status updates between modules are acknowledged. The modules use addressable data packets with error checking, packet acknowledgements and retransmissions to achieve a reliable invisible wireless control link. Data management of the system is relatively simple compared to the case of cardiology where ECG data had to be sent in an encrypted form [9].Since the established link between the secondary center and tertiary center had already been used for the purpose of radiology, haematology, cardiology and others, the bandwidth is sufficient enough to transmit the data of the chronic renal failure patients which are relatively less complex. Thus, at a time a greater number of patient's data can be sent over the same link for chronic renal failure patients.

IV. CONCLUSION

In this paper a telemedicine system with some decision making capabilities has been developed to provide treatment assistance to renal impairment patients in rural areas of eastern India. To do so, the system first prioritized the referrals of the patients in primary health care centers in rural areas and then sent the priority list via wireless link to higher centers. Clinical trials with the system has been done with 50 patients who were selected from the primary health care centers according to inclusion criteria. The concept was implemented in a clinical trial of 50 patients. The clinical trial of the patients was carried out for six months (June-Nov. 2007). These patients were advised to report to the non-medical staff at the primary health care center at an interval of one month over six months time to record their relevant parameters namely age, weight, plasma creatinine , blood pressure/diabetes status and results of proteinuria / microalbuminuria (if applicable).Prioritization was done by the system initially by demarcating the patients in various stages (I-V) on the basis of glomerular filtration rate (GFR) values indicative of creatinine clearance of patients and the presence of proteinuria (specifically for stage I). Further prioritization for patients falling under the same group and with the same GFR was done on the basis of the gradient in change of GFR, and status of blood sugar and hypertension. Using the prioritization algorithm proposed here, 27 out of 50 patients' information were sent in the first month to the tertiary center for quick follow up. Out of the remaining 23 patients, only 5 patients were given follow up dates at the tertiary center and the rest 18 patients were given medical advice through the telemedicine framework thus reducing the patient load of the tertiary center by almost 40%. The decision of the prioritization algorithm was matched with that of the physicians. An exception with patient 29 is noted since he has ended up in stage 3 from stage1. Though the system did not give him the maximum weight for prioritization, the physician prioritized him immediately after the stage 5 and 4 patients on the basis of clinical assessment and findings. This is because his renal failure had progressed possibly from some form of glomerulonephritis which do not fall under the purview of the system. Treatment for such patients are difficult to be done by any telemedicine facility since they require personal intervention of the nephrologists.

The telemedicine system utilized the wireless transceiver module TCM3-4DIO interfaced with the PIC microcontroller for communication of data between primary health care center and secondary center. The data communication between the secondary center and tertiary center is accomplished by exploiting the existing 512kBps line of WEBEL along with the database software developed by CDAC. The system ensures reliability in data transmission. With the facilities of the system, the patients were undergoing treatment from the tertiary health care center without physically attending the nephrologist's OPD at the tertiary health care center. Without the presence of this system, such patients would have to be treated by the physician at the primary health care center who would send each of the patient individually based on the plasma creatinine values to the tertiary health care center without fixing dates based on medical priority. In turn this would increase the load and also the cost of treatment incurred due to travel. However, further improvements in the system can be made by maintaining the status of diabetes of patients through teleconsultation with the diabetologist at the tertiary health care center. Also to deal with greater number of patients, finer prioritization on the basis of actual values of blood sugar and pressure and the course of medication being followed by the patient must be incorporated within the existing system.

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References

1. Rao Madhumathi, Pereira Brian J G, "Chronic kidney disease in India - a hidden epidemic Indian" Journal of Medical Research, July 2007
2. B.Das, S.Banerjee, "A smart diagnostic system for Doppler ultrasonography" Proc. of Bioengineering Conference, pp.275-276, 2002.

3. Smith HR, Ashton RE, Brooks GJ, "Initial use of a computer system for assisting dermatological diagnosis in general practice", Med Inform Internet Med., Apr-Jun;25(2):103-8,2000.
4. El-Solh AA, Hsiao CB, Goodnough S, Serghani J,Grant BJ, "Predicting active pulmonary tuberculosis using an artificial neural network", Chest. Oct;116(4):968-73,1999.
5. Monnier-Cholley L, MacMahon H, Katsuragawa S,Morishita J, Ishida T, Doi K., "Computer-aided diagnosis for detection of interstitial opacities on chest radiographs", AJR Am J Roentgenol. Dec; 171(6):1651-6, 1998.
6. García-Lizana, Francisca, Sarría-Santamera, Antonio, "New technologies for chronic disease management and control: a systematic review", Journal of Telemedicine and Telecare, 13(2), 62-68, 2007.
7. A.Hasan Sapci, "Chronic disease management and home care", Second National e-Health Congress, Turkey,2007.
8. A.Kolmann, D.Hayn, J.Garcia, J.D.Trigo, P.Kastner, B.Rottman, K.Tscheliessneig, G.Schreier, "Feasibility of a telemedicine framework for collaborative pacemaker follow up", Journal of Telemedicine and Telecare, 13: 341-347, 2007
9. Ravindranath, N. H., Usha Rao, K., Natarajan, B. and Monga, P.,Renewable Energy and Environment – A Policy Analysis for India,Tata McGraw-Hill, New Delhi, 2000.
10. www.webelindia.com(telemedicine projects by WEBEL ECS ltd)
11. www.cdac.in(CDAC medica informatics)
12. Harrison's principle of Internal Medicine, 16th Edition, Mc.Graw Hill .
13. Oxford textbook of Nephrology, Oxford University Press
14. www.embeddedcomms.com.au
15. Computer architecture and organization, J.P.Hayes
16. Review of Medical Physiology, W.F.Ganong, Mc. Graw Hill

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