Early Experiences of the Use of Remote Patient Monitoring for the Long Term Management of Chronic Disease

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Abstract

We describe our experiences of using remote patient monitoring to support the long term management and clinical intervention in patients with chronic disease, such as CHF. Within the project we developed new algorithms to determine from vital signs collected on a daily basis, those patients requiring clinical investigation for their condition. Our aim was for patients to achieve and sustain clinically recommended values for parameters. In our study, the telemonitoring prompted clinical intervention in 37% of patients. Our approach proved particularly effective for the newly diagnosed, and for those with long term issues of management.

1.   Introduction

It is estimated that there are over 17 ½ million people living with a long term condition in the UK, accounting for over 80% of GP consultations. With an aging society these numbers are only set to increase further [1]. Evidence has shown that even relatively small reductions in blood pressure in those with hypertension and blood glucose in diabetes mellitus can reduce their clinical risk significantly [2, 3]. It is vital that healthcare services are able to provide these gains for patients at an affordable cost. Remote Patient Monitoring (RPM) has been identified as a potential tool to manage this demand for health care [4]. To date there have been many projects that have evaluated the technology [5], however most have concentrated on detecting and managing the acute exacerbations that arise from chronic disease (particularly CHF) rather than determine effective ways to manage the long term condition itself. This study aims to develop and evaluate methods that exploit both RPM in the patients' homes and protocol-based clinical interventions to achieve sustained improvement in disease measurements for three long-term conditions: chronic heart failure (CHF); Type 2 diabetes mellitus; and essential hypertension, thereby reducing the risk of developing the complications of the disease.

2.   Methods

Our study was based in Chorleywood Health Centre, a medium sized general practice to the NW of London. From a total population of 6000 registered patients, 724 were determined to have CHF; type II diabetes mellitus; and essential hypertension, some having two or more. 173 were chosen randomly and invited to take part in the study. Of these 51 accepted the invitation to participate in the study.

Each participant was provided with an RPM unit for a 12 week period, the study having three such cohorts over a nine month period. We had a further set of 3 patients having the equipment for the entire nine month period and a set of 3 patients with no equipment. We used a commercial RPM system (Care Companion, AMD Telecare, North Chelmsford, MA, USA) that consisted of a unit with a touch screen device to allow manual entry of certain data (glucose) and attached peripheral devices to measure automatically appropriate medical values. Those with CHF were given weighing scales, SpO2, and BP unit; those with Diabetes a glucometer; and those with Hypertension a BP unit. Each participant was asked to enter daily physiological measurements. Targets were set for each group based on best practice guidelines [6, 7]: BP of 140/85mmHG for non diabetic patients and 130/80mmHG for patients with diabetes, HbA1c of 7% (8.6 mmol/L). CHF was managed by monitoring weight, BP and SpO2 for significant change.

The data was sent via the participant's telephone line to a server held at the Health Centre and could be accessed and viewed via a website. A chart of the data was created for each patient and this was hyperlinked into the EPR (electronic patient record). The primary healthcare team reviewed each patient whose data lay beyond the threshold defined by our intervention algorithm at regular case conferences and clinical interventions were agreed.
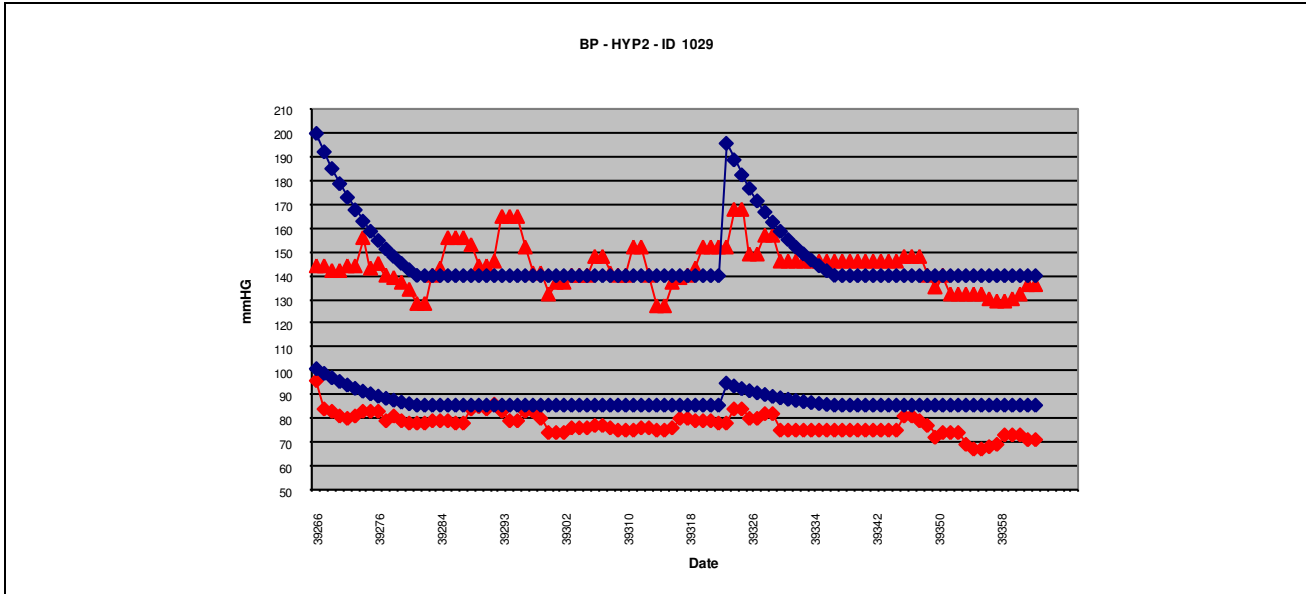
Figure 1. Personalized automated intervention protocol for a hypertensive patient with successful addition of a calcium blocker to better control the systolic blood pressure.

3.   Results

After 6 months of the study, 2 cohorts had completed the 12 week trial, giving data on 29 patients (mean age 70, 17 female). 11 patients had essential hypertension as their primary long term condition, 8 had chronic heart failure, 7 had type II diabetes mellitus, 2 had chronic heart failure and type II diabetes mellitus, and 1 had all three conditions. 9 participants withdrew from the study before they were due to be given the RPM units because of clinical or social reasons and further participants were recruited to replace. None withdrew during monitoring.

The algorithm has prompted clinical intervention in 11 patients (37% of the patients): of these 64% were in the CHF group, 18% in the Hypertensive group and 18% in the diabetes group. The average time elapsed before first intervention was 47 days (SD 21). Primarily these interventions (72%) resulted in changes to medication and health advice, however one hypertensive patient was referred for a pace maker after the discovery of a bradycardia due to heart block, and one CHF patient had two emergency hospital admissions during the 12 week period. These interventions have resulted in a mean shift reduction of 12mmHG Systolic and 2mmHG Diastolic in the hypertensive group.

4.   Intervention protocol

We developed a sophisticated personalised automated intervention algorithm within the project to improve the accuracy with which patients requiring intervention were recognized compared to existing systems based on a simple threshold. The specific goals were to reduce the number of false positive indications and to adapt automatically when a clinical intervention was made so that no further indications were given until sufficient time had elapsed for the intervention to take effect.

Our approach was to smooth the raw data by using a median filter over 3 days, which is effective at removing outlier values. We then wished to apply an adaptive threshold that was based on the patient's data, responded to an intervention and would eventually provide an indication should the patient data remain above the long term target value.

Such an adaptive threshold can be achieved by applying an exponential curve having an initial value that is 2 standard deviations above the current value (calculated from patients existing data), and decaying over a 14 day period to the long term target value. The threshold is seen to model well changes in the data when the patient responded to an intervention. The threshold also remained responsive to sudden changes resulting acute exacerbation.

The algorithm is shown applied to a hypertensive patient in figure 1 where the final target is set at 140/85. The smooth curves indicate the boundaries within which the data should lie to achieve best clinical outcome as described in the Map of Medicine [8]. To avoid needless triggers and alarms the boundaries are adjusted upward at the beginning of monitoring and after the introduction of an intervention, the value being set to 2 standard deviations above the current value.

A case conference run with the doctors and nurses of the team reviews the collected data and the clinical notes. Data is observed on a daily basis but unless swings are
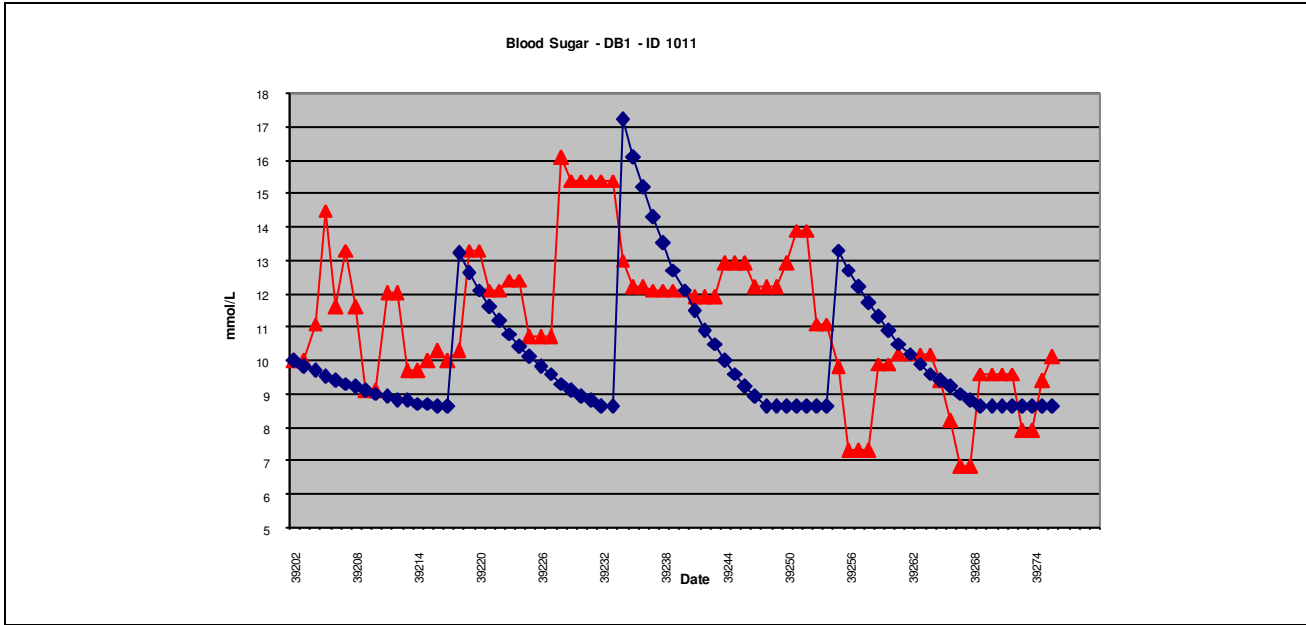
Figure 2.   Personalized automated intervention protocol for a newly diagnosed diabetic patient.
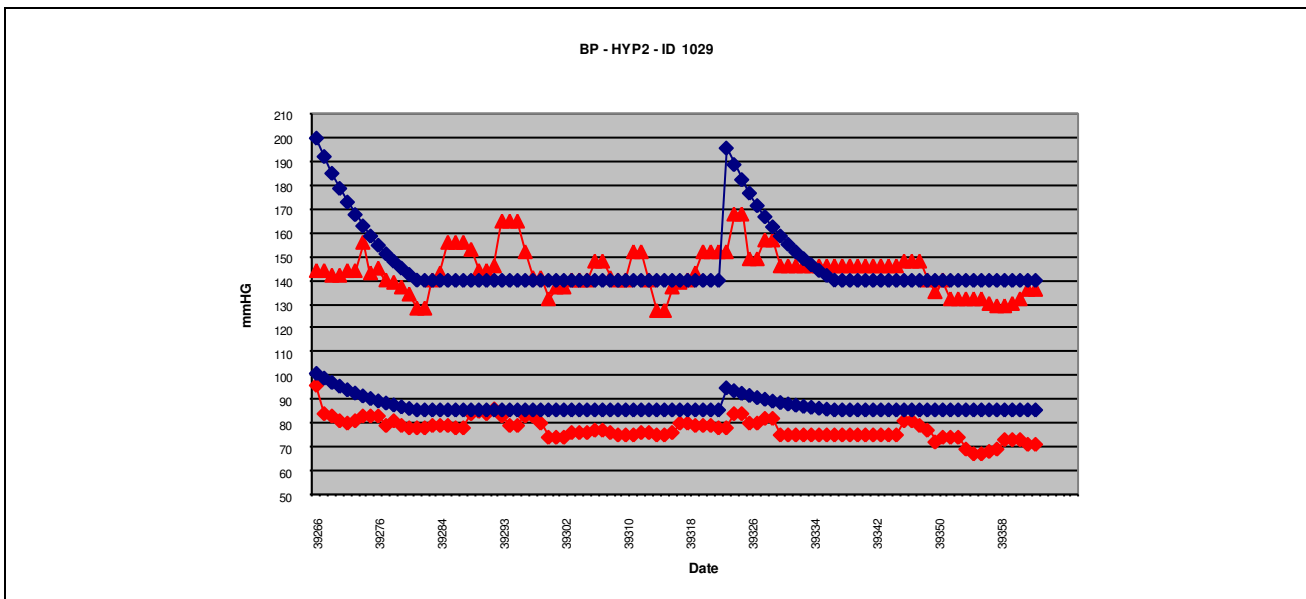

Figure 3.   Personalized automated intervention protocol for a diabetic patient having long term management issues and requiring repeated intervention.

extreme, data is reported on a weekly basis and reviewed for possible intervention every two weeks. Figure 1 shows the successful addition of a calcium blocker to better control the systolic blood pressure.

Figure 2 shows a diabetic patient unwilling to accept her newly diagnosed diabetes and treatment until there is eventual control of the blood sugar following repeated intervention and education.

Figure 3 shows the daily blood glucose readings for a patient known to have long term management issues of

diabetes. On each clinical intervention, the threshold is reset to a value higher than the current value and it can be seen to reduce back to the target value over a 14 day period. The patient refused nursing advice to rotate his injection site, his persistence with one site being due to his difficulty in coping when in his wheel chair – he is disabled because of a diabetic neuropathy – and his faith in his private diabetologist. Observing his results changed his thinking. The dose of insulin was then increased. The final change was to introduce Metformin.

5.   Discussion and conclusions

The personalized threshold algorithm was developed to be based on the patient's data, clinical target values and clinical interventions so that it might easily be applied automatically within a RPM system. When linked to their primary healthcare team, the need for clinical intervention is easily recognized and thus provides better and earlier disease management. Limiting the amount of time required to review the data by both reducing the number of alerts and filtering out those patients not requiring intervention contains work load and makes adoption of the system more likely.

Results suggest that 4 weeks is sufficient time in which to recognize a need to intervene clinically and that in 12 weeks it is possible to intervene enough to affect a change toward target. This reduces both the disruption of patients' lives and the cost of the service because the equipment can be reused quickly.

In the UK, the GMS contract has made general practice the key organization to care for chronic disease. But the clinical question remains – on whom and when should we intervene? A single occasional measure of a physiological parameter might fail to reveal poor care and deterioration in a patient's illness. A clinical response to a single reading of blood pressure can lead to excessive dosages and harm. In contrast in this study, clinical interventions were agreed upon by the team and carried out by both nurses and doctors in their clinics and in the patients' homes. The value of RPM was established quickly in the minds of the team as the results were reviewed and made any additional clinical work acceptable. In answering clinical questions further clinical tests were needed: blood tests; ECGs recorded; ambulatory ECG and blood pressure recordings made; and referrals arranged. The combination of technology and clinical skills possible in general practice was proven to be effective in responding to the data.

RPM used with automated personalized intervention algorithms and a clinical protocol was found to be very effective in the long term management of patients with chronic disease in this primary care setting. It was particularly effective in the case of newly diagnosed patients, patients needing change in medication, those unwilling to comply, and those with poor long term control, as it supported an aggressive targeted strategy for intervention. By improving the intervention algorithm, fewer false positive patients were detected, giving the users confidence to act on the information.

By shifting the focus of care away from managing acute exacerbations, clinicians can use RPM to recognize those of their patients who would most benefit from monitoring. The clinical information provided by RPM allows both healthcare professional and patient to confront issues together and resolve difficulties. Awareness of the physiological measurements and learning their value from the clinical team empowers patients in gaining self-determination in understanding and managing their own illness resulting in benefits for themselves, their healthcare professionals, and the health economy.

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