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Preliminary Design of Remotely Used and Monitored Medication Dispenser

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Abstract– Physicians are often considered as the final pathway for nearly all professional decisions about the use of health resources. Yet with respect to drugs, pharmacists are in many cases the final link between the medication and the patient. This approach of medication intake can be hazardous to the patient. Several mechanical as well as automatic medication dispensers incorporating alarm and automatic opening and closing mechanisms have been developed in the past. Current automatic dispensers incorporate features such as alarms, dose missed indicators followed by the access to the next dose, and simultaneous access to medication of different types. We are developing medication dispensing methods suitable for use in remote dispensing for opioid dependent patients. These include remote patient monitoring, facial image processing, and background processing techniques for monitoring and assessing the patient.

I. Introduction

Every day thousands of patients put their lives in the hands of medical professionals when receiving medication, with medications among the top most medical priority to society as a precautionary measure as well as cure. Inappropriate medication use limits beneficial patient outcomes from therapy, and at times can result in death.

Two forms of inappropriate use are medication errors and non-compliance. Medication errors account for 28% of all medical mistakes made by patients [3]. However, medication error rates have significantly increased over the years [1]. The death rate due to medication errors is more than 7000 annually in the US alone [2]. Death rates in untreated drug users and in non-compliant drug therapy patients, particularly those on methadone programs are also very high. A common way to minimize medication errors is the use of Dose Administration Aids (DAA's) [4],[5] (Fig 1], where doses of one or more solid oral medications can be packaged and organized according to the time of administration. Some DAA's have a patient's photo and identification details imprinted.

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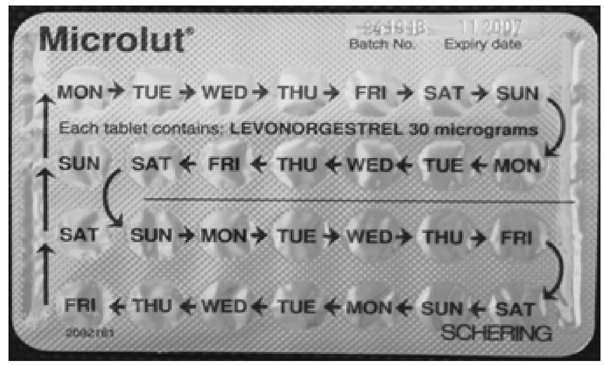

Fig 1. An illustration of a DAA. This type of aid is user friendly with a daily dose indicated on the package.

DAA's have several advantages [6]

- can be single or multiple doses,
- systematic arrangement per day and time,
- can easily check if medication is skipped,
- helps avoid double dosing [7].

Non-compliance is of two types, intentional and non-intentional, resulting from overuse, underused, or other types of misuse of medication [8]-[10], with direct negative effects on the patient's health. This is a well recognized, problem especially among the elderly and those on drug rehabilitation programs [10]. In some cases such as diabetes, epilepsy, hypertension, organ transplant and chronic diseases, medication compliance is also sometimes found to be poor [11]. Non-compliance can be controlled in hospital settings due to the presence of medical professionals [12]. However in residential settings where monitoring of the patient is either done by the patient or by family members, the risk of non-compliance increases.

The risk of non-intentional non-compliance of out-patients can be significantly reduced with the use of home medication dispensers [12]. Two types of such dispensers currently available are purely "mechanical" dispensers and also "automatic" dispensers.

Mechanical Medication Dispensers: Many studies have been carried out on medication dispenser mechanisms. Reference [13] developed a medication dispenser for one type of medication. The dispenser can be used for more than a week's dose. In this case the medication pills need to be removed from the packaging. Reference [14] developed a handheld device for dispensing medication from a packet, incorporating a dispensing mechanism that removes the packaging, releasing each in turn. Human error can be minimized in this kind of dispensing. A number of other dispensers have been developed utilising automation to improve on previous technology [15, 16, 17].

Automatic Dispensers: With the increasing influence of technology and automation in the field of healthcare, dispensers with automation and audio services are commercially available in market. E-pill is one such solid-medication-dispenser developed by E-Pill Medication Reminders Company which can contain nearly one month's medication. In addition it has an alarm system to alert the patient to take the medication according to the time set. The right medication slot opens when the alarm rings which makes sure that the patient takes the right medication at the right time. This device is potentially safer than the DAA's since incorrect medication usage is minimized. Due to this kind of safety in addition to its portable size this dispenser can be also used when a person is mobile.

Despite their advantages, none of the devices mentioned above prevent medication tampering or incorporate on-line assessment by medical professionals. Consequently intentional non-compliance is not reduced with existing home dispensers, since they do not include sufficient monitoring and security features.

Opioid Dependent Patients: Opioid dependent patients are prone to medication intake over long periods. It is found that in general these patients prefer take-home dosages [18]. Use of a home dispenser with these patients would require monitoring their drug use. Current assessment is generally limited to urine testing [19], although recently pupillometry has been found effective [20]. Pupillometry provides an objective measure of the intensity of opiate withdrawal in subjects during gradual opioid detoxification [21]. These assessment procedures, however, require a medical professional to visit the patient [22]. Furthermore, several studies have shown that internet based patient monitoring generally allows medical professionals to remotely administer their patients successfully [23, 24]. In addition some studies have demonstrated that use of computers and technology can reduce many medication errors [25, 26], and a remote interrogation system can potentially be as reliable as a visit to a physician's clinic [27].

We propose to develop a remotely monitored medication system which can dispense oral medication and enable assessment of patients by medical professionals. This medication dispenser is intended to reduce non-compliance among opioid dependent patients who are given oral take-away doses.

II. METHOD

Figure 3 shows a schematic representation of the medication dispenser equipped with a computer and with an internet connection, a data acquisition device (DAQ) and interface circuitry, cameras to monitor medication dispensing and the patient's facial expression, and a pupillometry device for patient assessment.

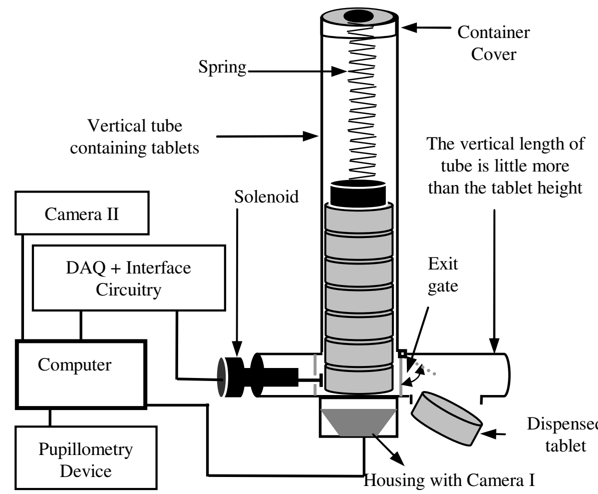

Fig 3. Schematic representation of the basic proposed single tablet type medication dispenser.

Remote Monitoring System: The internet based remote monitoring system comprises a patient monitor for communicating with the physician, a secure server and the physician's monitor to observe the patient. The overall system configuration is depicted in Fig 4.

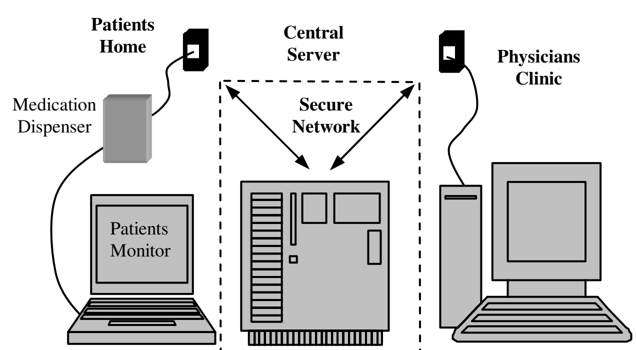

Fig 4. Overall System Configuration

The medication dispenser will be filled by a medical professional. The patient's site needs an internet connection. The same is required at the physician's clinic site. The device data captured will be transferred online to the physician's computer after the required signal processing and compared to the past data of the patient.

Automated Background Assessment:
Patient assessment will be carried out before and after medication intake. After connecting to the network and

establishing proper audio visual communication with the patient and the doctor the pre-medication assessment starts. The assessment will consist of

- Capture and collection of facial images
- Recording and monitoring patients speech and
- Pupillometry

The medication dispenser is programmed to communicate with the central server and upload the data. The uploaded data is evaluated by the monitoring module which runs on the central server. Upon receiving this data, the physician can compare it to the patient's history. The physician also compares the same with the data received on assessment after medication intake.

Supervised Dispensing and Consumption of Medication: Due to the monitoring, non-compliance from the patient can be minimized. The physician initiates dispensing of the medication upon receiving the visual feedback, when satisfied regarding safety and desirability of doing so, and can monitor consumption of the medication. In addition, details including medication type and dose, and date and time of the medication intake is recorded.

Image Processing and Artificial Intelligence:
Image processing and artificial intelligence has been used for detecting elements of facial expression and in speech processing [28, 29]. Detection of changes in normal behavior indicating opioid usage is proposed using imaging and artificial intelligence methods, such as trained neural networks and fuzzy logic systems. These would run as background tasks on the physician's PC, and would produce alerts when the patient's behaviour deviates from ranges considered normal for that patient.

Implementation of the above methods will be done using LabVIEW (National Instruments, Austin, TX) and Matlab (Mathworks, Natick, MA). LabVIEW will be used for device control, image and audio acquisition, user interface and secure internet communication. Matlab will be used for image and audio processing and applying Artificial Intelligence methods.

Fig 5 shows the medication use process which involves pre and post medication intake assessment, and medication dispensing. The dispensing technique minimizes a patient's tendency to become non-compliant, and allows assessment of the patient to be performed online. The data obtained from the patient can be stored for future reference.

III. Conclusions and Enhancements

A remotely used and monitored medication dispenser, with medication dispensing controlled by the physician, will assist in patient's safety and medication outcomes. Future work involves developing the physical dispenser, control and monitoring software then performing in-house and selected patient trials.

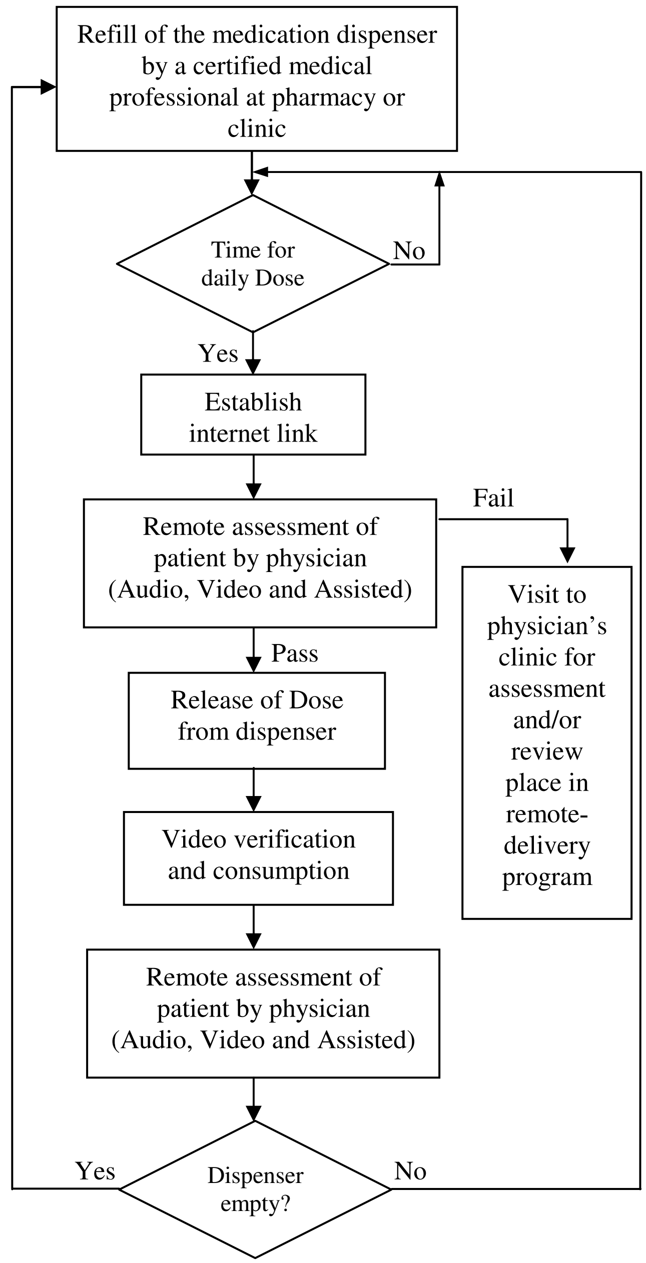

Fig 5. Flowchart of Remote Medication Use.

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