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Research Article

Conceptual Design of a Telemedicine System for Diseases such as Diabetes Type 1, 2 for Higher Efficiency in Disease Management & Treatment Patterns

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Abstract

The components of telemedicine are either electronic, mechanical or a combination of both. These have to be manufactured taking into consideration their specific requirements and the functions which they have to perform. The telemedicine system offers improved disease management and enhanced quality of care. The system should be kept debugged and virus-free. The patient's logbook is used to register details about the patient. These details include the test results, treatments being currently undertaken, and exercises. It would also contain a record of the treatment method carried out previously and the corresponding results. This information will then facilitate the patient to mark his progress and the caregiver to suggest better medication. Ultimately, timely & effective communication within the period is achievable.

Introduction

Purpose

The telemedicine system would facilitate communication between say for instance a diabetes patient and his GP [1]. The system will enable the physician to suggest a probable cure or at least provide immediate relief to the patient even when they are physically apart. It aims to serve the rural people who don't have access to the facilities instantly. The following are the requisite features of the telemedicine system:-

1) To define the requirements for the new telemedicine system (both monitoring and communication).

2) To explore possible system configurations using various design methods (TRIZ, systems models, and risk analysis).

3) To outline the embodiment of the preferred system concept.

Scope

The system attempts to open channels for proper communication to be established between the patient and the General Physician. The system is useful for patients suffering from diabetes, nurses, physicians, and health centers.

User characteristics

Diabetes is caused when the body loses its ability to use carbohydrates for energy generation. This in turn gives rise

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to increased blood sugar levels. Insulin is a kind of hormone made by the beta cells found inside the pancreas. Insulin transports glucose from the bloodstream into the various organs of the body. Glucose is a form of sugar which supplies energy to the body. Insulin is responsible for controlling the blood sugar level. In the case of Insulin resistance, the muscles, liver, and fat cells stop using Insulin effectively even though an adequate amount of Insulin is produced in the body. As a result, the pancreas reduces Insulin production in due course of time [2-4].

Amount of Insulin that needs to be supplied to a diabetic person: 1ml-5ml. Insulin is dissolved in liquids at varying strengths and is then used. Commonly used insulin saturations include U-100 and U-40. There are certain ingredients added to Insulin to maintain freshness and improve workability. Intermediate and long-acting Insulin is made to act longer with the help of such additives (Tables 1,2).

Ways to monitor blood glucose levels:-

- HbA1c (Blood Glucose Testing)
- Blood glucose meter

Table 1: Types of Insulin.

	Rapid Acting (lispo)	SHORTACTING (regular)	Intermediate Acting (NPH & lente)	Long Acting (Ultralente)
Onset	Within 15 min.	Within 30 min.	After 2-6 hours	After 6-14 hours
Peak Time	30-90 min. later	2-4 hours later	4-14 hours later	No peak time or small: (10-16 hours)
Duration	5 hours later	4-8 hours later	14-20 hours later	20-24 hours later

The various ways to supply the body with Insulin include:-

- Insulin pills
- Insulin shots
- Insulin pumps
- Insulin injections (Syringe)
- Injection pen
- Inhaled Insulin

Telemedicine system

To check for and diagnose diabetes, it is necessary to carry out a urine test which would test glucose and ketone levels from the breakdown of fat.

There are two kinds of blood tests used to diagnose diabetes, these are:-

- **Fasting blood glucose levels:** If the blood glucose level is found to bear a value higher than 126mg/dL twice, then the person is diagnosed with diabetes. However, if it lies between 100-125mg/dL (milliliters per decilitre), it is said to be Prediabetes or impaired fasting glucose level.

Both these conditions suggest the probability of type-2 diabetes.

- **Haemoglobin A_{1c} Test:** Besides helping patients to monitor and control their blood glucose levels, this test also enables diagnosis of Diabetes and identifying Prediabetes. The test indicates the condition according

Table 2: Types & Characteristics of Diabetes

Type	Age -Group	Cause	Effect	Symptoms	Precautions & Treatment
Type-1	It is commonly found in children below the age of 20.	Exact cause is not known. Probable causes include genetics, viruses, and autoimmune problems.	Insufficient or negligible amount of insulin produced in the body	1. Fatigue 2. Blurred vision 3.Unexplained weight loss 4. Hunger 5. Uneasiness 6.Increased thirst and urination 7.Weakness 8. Sweating 9. Nervousness 10.Rapid palpitations Stomach Pain	1. Healthy & Balanced Diet 2. Exercises 3. Daily insulin supply to the body in the form of injections, pills, etc.
Type-2	Comment y found in adults.	1. Hindered response towards Insulin (Insulin Resistance). 2. Sugar (Glucose) doesn't enter cells. 3. Obesity 4. Low physical activity 5.Poor Diet	1. High Blood Sugar Level 2. Hyperglycemia	1. Blurred Vision 2. Fatigue 3. Hunger 4. Increased thirst & urination 5.Erectile dysfunction 6. Pain & reduced sensation in the limbs. 7. Slow healing	1. Healthy & Balanced Diet 2. Exercises 3. Weight Control 4. Accurate & Regular monitoring of blood sugar level. 5. Proper medication
Gestation al Diabetes	Pregnant women	1. High Blood Pressure; 2.Excess amniotic fluid; 3. Prepregnancy overweight conditions.	1. Pregnancy hormones interfere with the activities involving Insulin. 2. High risk of causing type-2 diabetes. 3. Can cause cardiovascular diseases later.	1. Blurred vision; 2.Fatigue; 3. Increased thirst and urination; 4. Weight loss but increased appetite; 5.Increased chances of infection	1. Healthy, Timely and Balanced diet. 2. Accurate monitoring of the health and size of the fetus through ultrasound and non-stress tests. 3. Extra Iron and Calcium intake. 4. Insulin therapy.

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to the blood glucose level detected, levels indicate:-

- Normal - 5.7%
- Pre-Diabetes - 5.7% to 6.4%
- Diabetes - 6.5% or higher

Higher blood glucose levels increase the susceptibility of the body to other problems such as:-

- Blurred vision
- cardiovascular diseases
- kidney disease
- stroke
- Nerve damage

- **Oral glucose tolerance test (OGTT):** The test takes around 3 hours in which first a sample of flood is taken and tested. The person then is given a sample of glucose of around 75mg to drink followed by another round of blood glucose level testing after 30-60min.

The results and their interpretation are as follows:-

- 60-100mg/dL after fasting
- 200mg/dL after 1 hour of fasting
- 140mg/dL after 2 hours of fasting

} Normalcy Conditions

- 140mg/dL-200mg/dL after 2 hours of fasting → Pre-diabetes
- Higher than 200mg/dL after 2 hours of fasting → Diabetes

The test requires the insertion of a needle to draw blood which could be troublesome for some patients. Other risks associated with it include:-

- Excessive bleeding and hematoma
- Infection
- Nausea, blackouts
- **Non-fasting (Random) blood glucose level**

It is another testing system to monitor the blood glucose level using a portable device called a Glucometer. It comprises test strips and small needles, known as lancets. The strip determines the blood glucose level with the help of a chemical substance and uses the digital medium to display results.

Normal blood glucose level lies within the range:-

- 70-130 mg/dL before taking meals
- Less than 180mg/dL post-meals

Blood glucose levels lower than the above-mentioned values indicate hypoglycemia, hyperglycemia, however, is caused when the values lie at higher ranges than those mentioned.

Risk includes pain sensation due to the needle-prick (Figure 1).

Some other factors that increase the risk of developing type-2 diabetes include race or ethnicity, genetics, and age.

Regulations and standards

There are several regulatory standards framed to ensure that patients are not deprived of their essential rights. Antitrust, state licensing, and other such state laws covering liability and malpractices do not create a congenial atmosphere for telehealth in the present scenario. The existing laws are still in the development phase and need to be established in a manner that encourages the telemedicine system [5-7]. Medical practitioners are supposed to deliver their services within their states and as of now providing services across borders is yet to be legalized. John Oxedine, the State Commissioner of Fire Safety and Insurance of Georgia developed the Georgia Partnership for TeleHealth in collaboration with the state medical board and the state insurance industry. This incident laid the foundation for the legalization of the telemedical system.

Functional properties

- The telemedicine system offers improved disease management and enhanced quality of care.
- Eliminates the need for manual data recording and transfer of measured values.
- Physicians can access the data anytime via the Internet and can give appropriate suggestions. They can also correct any deficiency or lacunae in the current treatment pattern.

Physical properties

1. Bluetooth enabled meter
2. Wireless transmission services in mobile phones, laptops, etc.
3. Real time transmissions
4. Automatic transference of patient's test results in their

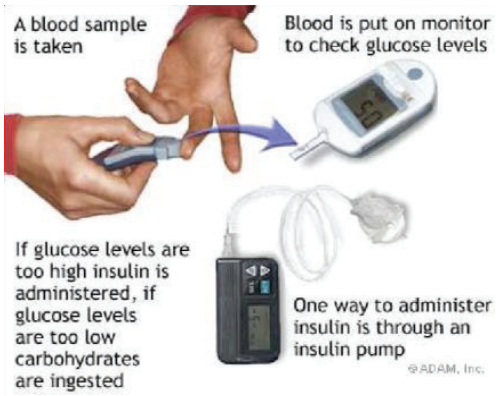

Figure 1: Insulin Administration (*Glucotest*, Eckman 2010).

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online log book. The details can then be accessed by their caregivers.

5. Internet connection
6. Disk storage space

Interface requirements

- **Administrator section:** This section will be managed by the patients who will have administrative rights and can grant accessibility rights to their caregivers. Its key function is to provide security to the system.
- **Data section:** The patient's data should be accessible to the caregivers and should be secure as well (Table 3 & Figure 2).
- **Alerts:** The GP can set alerts about the schedule of exercises and prescribed medicines with the help of various user-friendly features such as IMs (instant messaging), emails, text messages, etc. Any change required in the schedule can also be notified to the patient instantly.
- **Add-on (s):** Availability of add-on (s) like e-books on diabetes, health guides, exercises, and training programs, blogs. Besides this, it can also be used by caregivers for advertising and hosting diabetes-related information to attract potential customers.
- **Online store:** A kind of medical store where every medicine can be made available in the required amounts is another desirable feature. In case, a certain medicine is not available the physician can provide guidance to the patient on an appropriate alternative.

Environmental conditions

Any telemedicine revolves around the use of electronic devices for testing, storage, and transmission of patient data (Figures 3,4). It thus poses the threat of e-waste, exposure to excess radioactive radiation, etc. However, at the same, it can also be considered as an environmentally friendly and cost-effective method since it helps save a lot of paper which would have otherwise gone wasted recording and maintaining data and other details.

Table 3: The essential features of the interface have been shown above (*Data Transmission*, incentre.medical.phillips.com).

General image viewer
Image manipulation
Runs in a browser
Platform independence
Complete access to patient records
User authentication
Realtime teleconsulation
Session management
VPR concept
COMIS view
Potential for data mining
Fault tolerance
Encryption of patient data
Patient record privacy

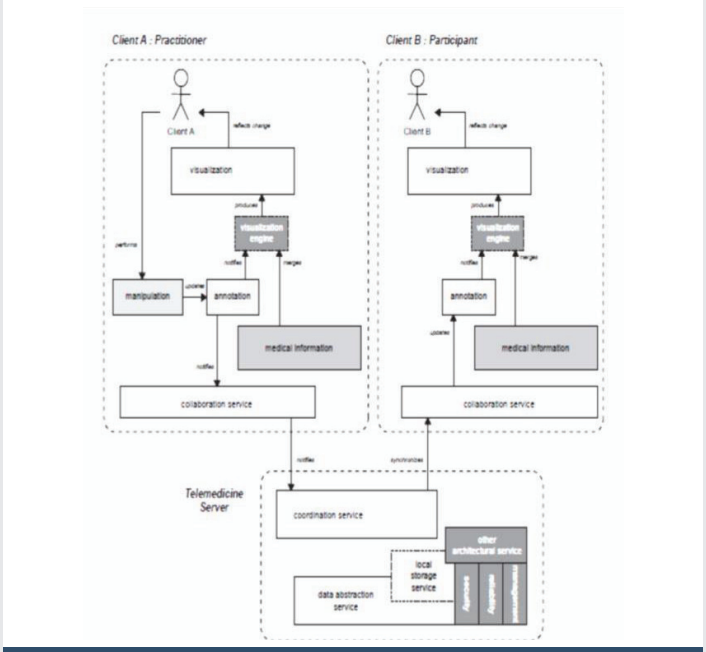

Figure 2: Flowchart about database management system.

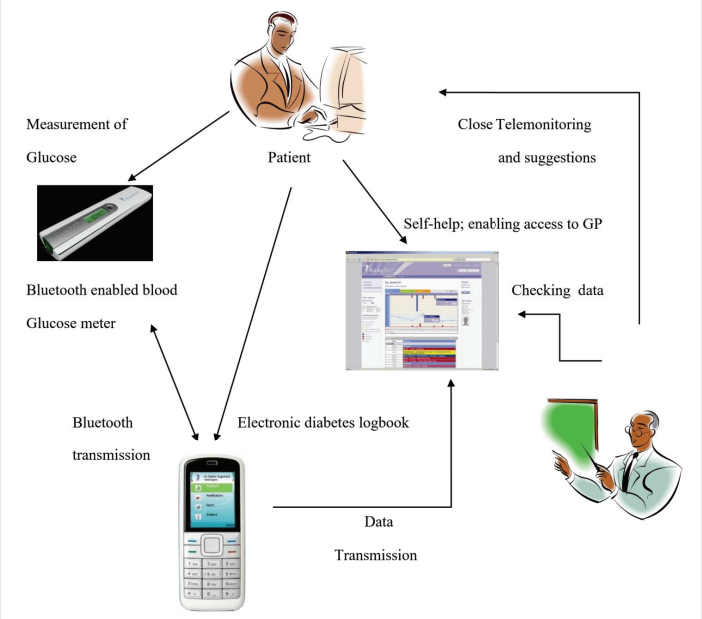

Figure 3: Telemonitoring, access to GP, teletreatment & information transmission.

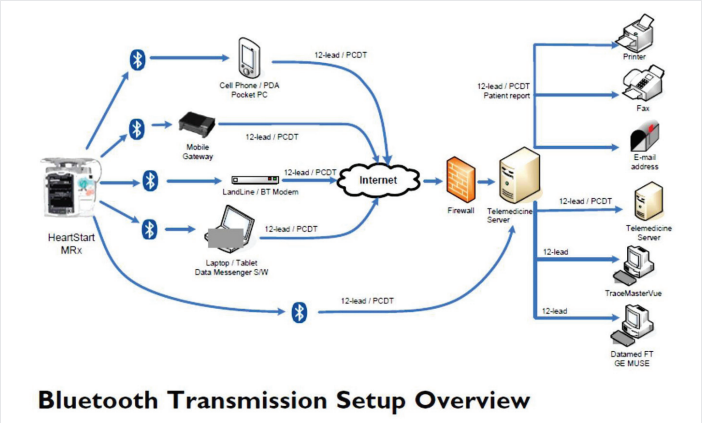

Figure 4: Data Transmission (Data Transmission, incentre.medical.phillips.com).

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Maintenance

It is one of the most important factors to be considered. The physical conditions and cleanliness of gadgets and devices used here must be properly taken care of. At the same time, the software used for telehealth services needs to be updated periodically such that no loss of data takes place (Tables 4,5).

Disposal

Older data forms that are no longer useful shall be erased from the system to avert confusion. The hardware components must be reused after use.

Schedule

(Table 4)

Validation

The installation can be verified using the following URL,

http://<*IP_addr_or_Domain_name*>/ems/MRxtest.mrx?SourceName=test. (Data

Implementation, incentre.medical.phillips.com)

For testing within the firewall, the following URL can be used,

http://<*IP_addr_or_Domain_name*>/ems/MRxtest.mrx?SourceName=test or http://<*Telemed_machine_name*>/ems/MRxtest.mrx?SourceName=test. (Data

Implementation, incentre.medical.phillips.com).

Table 4: Process – Monitor.

Step	Task	Duration
1	Purchasing the Bluetooth device and installing the necessary software.	2 days
2	Configure the software for 12 lead transmission	30 min.
3	Prepare the hardware, physical location, and total number of connections required.	2 days
4	Set up the Internet service protocol	1 day
5	Set up the dial-up internet account for a Bluetooth modem	1 day
6	Establish a dedicated analog phone line for fax	1 day
7	Set up & test the telemedicine system	2 days
8	Install & configure the application	1 hour/ machine
9	Test & verify the system	2 days

Table 5: Some of the necessary distribution and storage requirements.

Data to transmit	Data in KB	Transmission Interval	Approximate Storage Required	
			Per year	Per month
Periodic Vital Trends	5 KB	1-min.	2.63 GB	0.22 GB
	1 KB	5-mins.	0.53 GB	0.04 GB
Event & Periodic Vital Trends	15 KB	1-min.	7.9 GB	0.66GB
	1 KB	5-mins.	1.58 GB	0.13 GB
12 Lead Reports, Events and Periodic Vital Trends	45 KB	1-min.	23.65 GB	2 GB
	9 KB	5-mins.	4.73 GB	0.4 GB

Manufacturability, distribution and storage requirements

(Table 5)

Installation

The steps to be followed for installing the Bluetooth mobile are as follows:-

Go to the configuration menu.

⇩

Press the Menu Select Button

⇩

Select **Data Transmission,** using the navigation bars.

⇩

Select Phone/Mobile Settings from the drop-down menu.

⇩

Select **Add Profile**

⇩

Click on **Done.**

Training of personnel

Given the complicated nature of the system, it is imperative that adequate training be provided to the task force, including the designers, engineers as well as workers (Table 6).

Safety

It is very important to keep up the safety of the system. The system should be kept debugged and virus-free. Also, it has to be necessarily ensured that the hardware poses no physical threat to its users.

Cost

The cost of the system must be kept to a minimum such that it doesn't put any strain on the patients as well as the caregivers or any other user.

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Table 6: The skill sets required against given tasks have been shown above (*Data Transmission*, incentre.medical.phillips.com).

Task	Skill Level
Configuring HeartStart MRx	• Knowledge of HeartStart MRx • Ability to determine cell phone or modem settings
Setting up the cell phone or Bluetooth device	Ability to determine cell phone or modem settings
Setting up the hub (machine running HeartStart Telemedicine Server)	If you do not have an Information Technology (IT) professional (or someone with the skills listed below) to install and configure the hub, it is recommended that you purchase a server with the Microsoft operating system pre-installed.
Installing and configuring the HeartStart Telemedicine application on the HeartStart Telemedicine Server and the HeartStart Telemedicine Viewer machines	If you will be installing and configuring the hub and integrating it into an existing network, you should have the following skills: • Experience installing the Microsoft operating system that you will be using • Experience setting up an IIS server • Experience addressing security issues, such as firewalls, anti-virus software, authentication, and encryption • Experience installing and configuring a fax modem on a server • Experience setting up networks
Testing and troubleshooting	• Knowledge of HeartStart MRx • Knowledge of HeartStart Telemedicine • Experience installing the Microsoft operating system that you will be using • Experience setting up an IIS server • Experience addressing security issues, such as firewalls, anti-virus software, authentication, and encryption • Experience installing and configuring a fax modem on a server • Experience setting up networks

Documentation

The patient's logbook is used to register details about the patient. These details include the test results, treatments being currently undertaken, and exercises. It would also contain a record of the treatment method carried out previously and the corresponding results. This information will then facilitate the patient to mark his progress and the caregiver to suggest better medication. The table below shows an example of a documentation file (Table 7).

Table 7: Practice guidelines for teledermatology (2007)

Data Element	Tag (group, element)
Patient ID	(0010,0020)
Issuer of Patient ID	(0010,0021)
Patient's Birth Date	(0010,0030)
Patient's Sex	(0010,0040)
Other Patient IDs	(0010,1000)
Patient's Weight	(0010,0040)
Patient's Address	(0010,2154)
Patient's Telephone Numbers	(0010,2154)
Additional Patient History	(0010,21B0)
Reason for Study (64 characters)	(0032,1030)
Requested Procedure Description	(0032,1060)
Study Comments	(0032,4000)

Conclusion

Adequate & timely reporting of diseases is a precursor to effective treatment mechanisms. The GP plays a timely & leadership act in handling and monitoring every act of patient – care such as appropriate nursing requirements. The point of action while staying remote can serve as a holistic treatment venue if certain monitoring devices & care are provided to the patient without laborious movements & time spent.

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