Urine Volume Detection Methods for Dengue Patient Management

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***Abstract*— Dengue fever is an acute, mosquito-transmitted viral disease characterized by fever, headache, arthralgia, myalgia, rash, nausea, and vomiting. Infections are caused by any of four virus serotypes (DEN-1, DEN-2, DEN-3, and DEN-4). The incidence of dengue is increasing in most tropical areas throughout the world. Dengue is a systemic viral infection transmitted between humans by *Aedes* mosquitoes. For some patients, dengue is life-threatening illness. There are currently no licensed vaccines or specific therapeutics, and substantial vector control efforts have not stopped global spread. The dengue to be ubiquitous throughout the tropics, with local spatial variations in risk influenced strongly by rainfall, temperature and the degree of urbanization. There are about 390 million dengue infections per year. There is no specific treatment for the infection, and management is only supportive care with judicious fluid management during the critical phase coupled with continuous monitoring. Urine volume detection is a one of the major part of the fluid management for dengue patient. In Sri Lanka also dengue is a famous threat for humans. Measuring the urine output of the patients regularly is very critical for medical treatments and currently it is done by measuring it manually. But it is a very difficult for high number of patients in a hospital. This study was conducted to investigate about urine volume measuring devices and their methods.**

KEYWORDS – Urine volume detection, methods, Capacitive, Magnetic, Optical sensor

I. INTRODUCTION

Dengue causes the greatest human disease burden of any arbovirus, with an estimated 10,000 deaths and 100million symptomatic infections per year in over 125 countries[1]. Roughly half of the global population currently lives in areas that are environmentally suitable for dengue transmission. Dengue is transmitted to humans by *Aedes* species mosquitoes, which thrive in tropical and sub-tropical urban centers around the globe. In combination with these global trends, rising temperatures attributed to climate change have increased concerns that dengue will intensify in already endemic areas through faster viral amplification, increased vector survival, reproduction and biting rate, ultimately leading to longer transmission seasons and a greater number of human infections, more of which are expected to be severe. Increasing temperatures may further exacerbate this situation by enabling greater spread and transmission in low-risk or currently dengue-free parts of Asia, Europe, North America and Australia[2].

No specific treatment for dengue fever exists. Your doctor may recommend that you drink plenty of fluids to avoid dehydration from vomiting and a high fever.
While recovering from dengue fever, watch for signs and symptoms of dehydration. Call your doctor right away if you develop any of the following:

- Decreased urination
- Few or no tears
- Dry mouth or lips
- Lethargy or confusion
- Cold or clammy extremities

So measuring urine output of a patient is the major thing in fluid management of a dengue patient. In hospitals, there is no any automated device for measuring urine output of a dengue patient. The usual way of the measuring urine output is manual periodic measuring. But it is difficult and uncomfortable way for higher number of patients in hospital. As compared at the hospital setting, patient's fluid input is carefully recorded and mostly administered by the automatic devices. In the same setting, urine output is practically the only parameter consistently used by the clinic not yet monitored electronically. Currently, a few devices are presented to claim about the effective ability to measure urine output in assisting the hospital service. The current paper describes different methods for measuring urine output of a dengue patient and about existing urine output measuring devices. Specially this paper, describes working methods of these devices, main functionalities of these devices, technical capabilities and their weaknesses.

II. HISTORY OF URINE VOLUME MEASURING DEVICES

Two ultrasonic sensor based solutions were developed in late 90's. One of them is used VM220 ultrasonic temperature sensor with Hewlett-Packard 1000 computer[3]. Other one is used Urotrack Plus-220 sensors connected with Hewlett-Packard 78709A. But these two devices accuracy have low accuracy and they are unstable minutes by minutes. Moreover, these products were discontinued and did not put in a market.

In 2009, Medynamixt ate lunch on another electronic automatic urine meter, called "Urinfo 2000". This was the first urine monitoring device and it was introduced to the Israel market. It has three main parts.

1. Electronic digital monitor
2. The disposable measurement unit
3. The flow detector

This device was used technology to turn urine into uniform drops and then converts the drops to exact volume measurements using an optical drop reader. This delivers precise urine measurement at the bedside with an easy to read digital LED readout, eliminating the messy guesswork of measuring urine from traditional urine bags. The readouts can be synced with various electronic health records, eliminating the need for health care providers to manually measure the urine output and then record the data. Hersh et al. (200), had compared the accuracy of Urinfo2000 with the accuracy of standard nurse-handle DK-3460-Unometer. The average error of automatic device was found at 8% compared with up to 23% from the nurse records. Most of the nursing staffs we convinced that the use of the digital meter was every handy. This automatic device has been proven to be significantly more than manually recording.

However, this device has lack of ability to transmit the collected data into the ICU monitoring system. Therefore, nurses still have to do collecting measurements. Since this device does not transmit data into system, Urinfo2000 did not become a solution for reducing nurses working range. Urinfo2000 device shown in Figure 1.

Figure 1: Urinfo2000 device

III. OTHER METHODS FOR MESURING URINE VOLUME

FLOAT SENSOR BASED DEVICE

In Otero et al. (2009)[4], They introduced the development of a device for automatically measuring and monitoring the urine output of critically ill patients. According to their design, they hope to obtain a powerful and simple monitoring device that can recognize the filling level of two different-sized containers. There are two containers with different capacities. The float allows each sensor to detect when the container is full. It is recommended to use a smaller container to detect low urine output with precise and continuous monitoring. This operation is based on the following assumption. If the patient produces at least 5 liters per day, the actuator will be triggered 25 times, but if it does not reach the expected time. After the urine is full, it will be empty and needs to be measured again. For patients who produce normal urine or suffer from polyuria, when filling small containers, the urine content will not be released, but start filling large containers.

Using a smaller container to guide the release point will be more frequent and will reduce the workload by doing as much work as possible. In order to complete the task without any supervision, the detector must accurately perform operations when the container is completely full, because once the container is full, the urine produced will not be recorded before being emptied. These release valves are adjusted using linear solenoids controlled by a microcontroller (Atmel AT89S52). The maximum recording time of this controller is about 327.5 hours (about 2 weeks). As long as the patient produces at least 15 ml of water every two weeks, there is enough time to read the filling status, release its contents by activating the actuator when needed, and trigger an alarm when the target is not reached.

The control software is developed using the Java programming language and can receive readings from the microcontroller via the RS232 port. The doctor determines the treatment goal based on the patient's weight. This program calculates the maximum time that the small container should be filled, (t1) refers to the state of urine filled into the small container within the expected time, (t2) is the maximum time required to fill the large container. When the microcontroller receives data indicating the complete state before the t1 period earlier, the goal is reached, which is not necessary for accurate monitoring. Therefore, the valve will not open and the larger container will be filled. However, if the signal arrives after the t1 period, the controller will turn on the LED light to indicate that the target has not been reached. In this case, precise monitoring is required. When the small container is full, the actuator will start and the timer will reset to measure urine output again. At this time, if the small container is filled again in t1, but the larger container is not filled before t2, the alarm will still be turned on. In either case, when the larger container is full, the actuator will be active. Nevertheless, the prototype still has various mechanical problems Operate valves and actuators during operation.

The prototype of the method is shown in Figure 2.

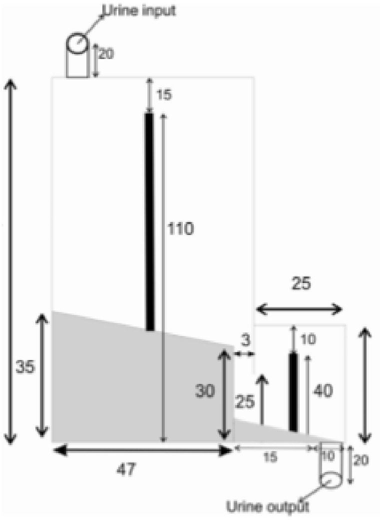

Figure 2: Design of the containers and component placement

CAPASITIVE BASED URINE FLOW METER

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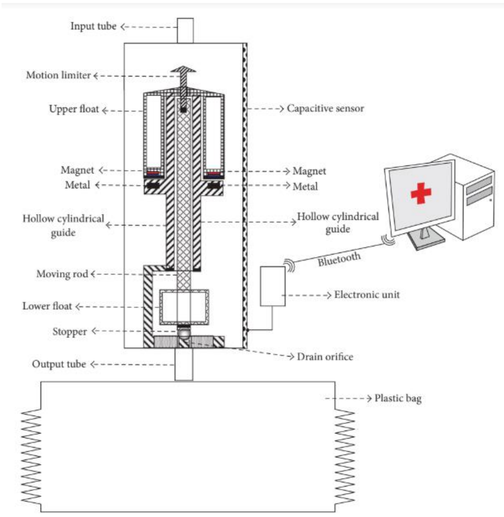

Figure 3: Device design

This device has a container with a single 90 mL chamber[7]. This container receives the urine through a flexible tube, which in turn is connected to a Foley catheter. In its outer wall it has a capacitive sensor. The longitudinal blade of the capacitive sensor must be at least as long as the container's height to provide a correct measurement of the height of the column of liquid (urine) inside the container. An evaluation of the use of capacitive sensors for measuring the amount of urine within a rigid container can be found in [20]; when used to measure minute-by-minute UO the error of these sensors is below 5%.

Once filled, the urine collection container will be emptied automatically without the need of power. To this end, the device uses magnetic forces to prevent activate the emptying mechanism of the container until it is almost full of urine. The drain orifice is closed by a plug located at the end of the movable rod connected to the two floats. In the absence of magnetic force, the small amount of liquid in the container is enough to make the float pull up the rod and the stopper, thus making trigger clearing. But magnetic forces prevent this situation from happening until the container is almost full; only then can buoyancy overcome the magnetic force. The magnetic force disappeared because the magnet moved away from the metal surface. Before magnetic forces can reappear, most of the liquid in the container must exhausted. Figure 3 shows device design.

The capacitive sensor that used was manufactured by Sensor technics GmbH. An interface circuit was built to enable communication between the sensor and a serial port to Bluetooth adapter, which sends the readings to and receives the commands from the central PC, although any other mechanisms of wired or wireless communication with the PC could have been used. The UO readings are acquired by a Java program running on a PC, which provides the health care staff with minute-by-minute measurement of the patient's UO and permits the triggering of alarms if this production deviates from the therapeutic goals.

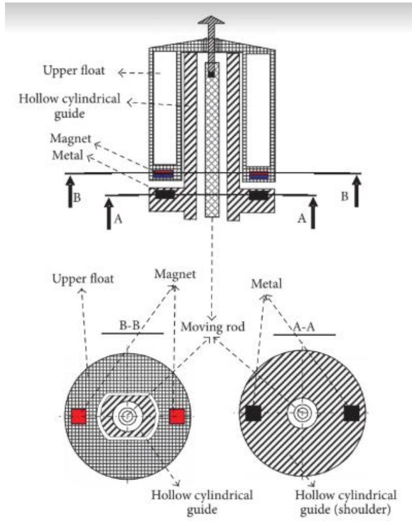

Figure 4: Location of the magnets and metal pieces in the upper float and on the shoulder of the hollow cylindrical guide.

A disadvantage of the device presented in above when compared with the manual urine meters currently used in critical care units is its use of metals and magnets. Manual urine meters can be made entirely of plastic and therefore are MRI compatible. This device should be disconnected from the patient before performing an MRI. Also this device communicates with the central PC by using Bluetooth technology. But it is short range communication technology. So it is the weakness of this device.

II

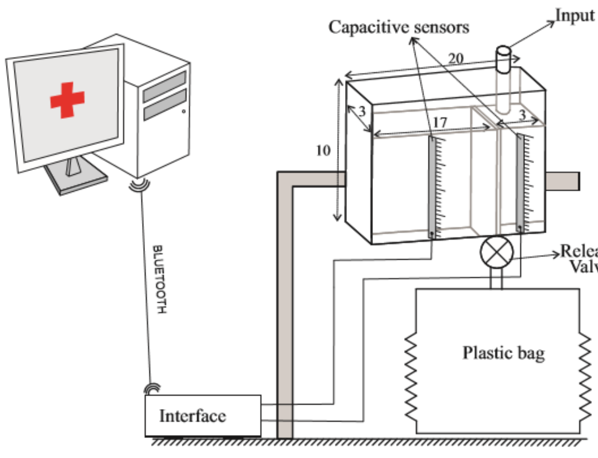

Figure 4: Device design

This device concept is based on two parallel plate capacitive sensor[8]. It is possible to measure the height of the column of liquid accumulated in a container made of dielectric material from the exterior by using a capacitive sensor. A common type of capacitive sensor is based on a coplanar-plate capacitor. These sensors are made up of two elongated conductive blades placed in parallel, at a distance d of each other. In our case, the length of the blades must be at least equal to the maximum height of the column of liquid to be measured. The blades should be placed lengthwise along the container's vertical dimension. The capacitive sensor measures the height of the liquid column. The error in the measurement of the height will grow proportionately with the area of the container when calculating the volume of liquid. Thus, to accurately measure small volumes of liquid, the area of the container where the liquid accumulates must be small.

In this concept, a signal conditioning circuit is used to measure the capacitance by converting capacitance variations into a voltage modulation. Since the capacitive sensor is a passive component, an excitation signal is required for the measurement. A high-oscillation frequency nearby the resonance frequency of the circuit is preferred for the excitation in order to achieve a low electrode plate impedance and to maximize the sensitivity to the height of the column of liquid. The excitation wave usually has a square or trapezoidal shape. A triangular waveform can also be used to allow a simpler amplifier with resistive feedback. However, a sine wave offers better accuracy at high frequency. Then, the signal is amplified, demodulated and filtered for further processing and A/D conversion. Sensors excited by a continuous wave signal usually use synchronous demodulators, which offer high precision and good rejection of out-of-band interference. The synchronous demodulator behaves essentially as a double wave rectifier, making this correction in sync with the excitement signal or synchronism of the circuit. During the first half of the cycle, the excitation signal value is superior to a reference, and the demodulator works as a rectifier inverter. During the second half of the cycle, the excitation signal is lower than the reference and the demodulator works as a follower of tension, so that the entrance to the demodulator appears in the output with a unit gain. Finally, a low pass filter removes the frequency of the carrier and other harmonics of higher-order, producing a ripple-free output. The amplitude of the rectified and filtered signal is related to the magnitude of the height of the column of liquid, while the polarity indicates the sense of displacement.

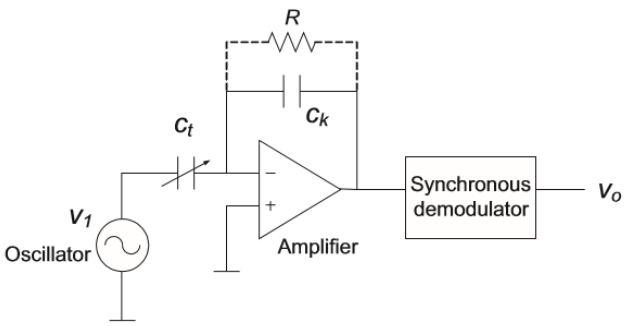

Figure 5: Electronic circuit of the device.

The electronic device sends the measures of the sensors via Bluetooth technology to a PC which calculates the urine output from this information and the supervises the achievement of therapeutic goals. The electronic unit takes readings from them and sends them via Bluetooth every 5 seconds to a Java program installed on a PC. This also carries a higher cost of production which makes it not ideal for the clinical conditions where each person has to buy his own device for their urine measurements.

HIGH PRECISION SCALE BASED URINE FLOW METER

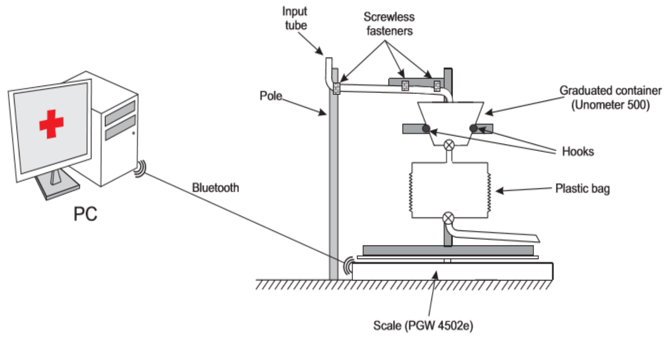

Figure 6: Device design

In this concept, to build our device we used the high-precision industrial scale PGW 4502e, built by Adam Equipment Inc[6]. It has an accuracy of 0.01 g and a maximum capacity of 4500 g. They also used the commercial urine meter Unometer 500 built by Unomedical. The urine meter consists of two containers. One is a graduated plastic container with 500 mL of capacity which is equipped with a top opening with a filter that is used to equalize the internal and external pressures without risk of bacterial contamination. The second container is a flexible polymer plastic bag with 2000 mL of capacity. The containers are connected by a rigid tube and a valve, which in our device is always open; thus the two containers can be viewed as a single compartment. The Foley catheter connects to a polymer plastic, flexible, transparent, 110 cm length tube that is connected to the graduated container of the Unometer 500.

They attached a metal structure built with Bosch profiles to the scale's pan to hold the commercial urine meter. The graduated container of the Unometer 500 is equipped with two hooks, one placed on each side of the container. They have used them to hang the device from the Bosch profile structure. Two screwless fasteners hold the input tube to the metal structure, and a third screwless fastener fixes the tube to a vertical pole. The purpose of the pole is to ensure that the input tube always lies in such a way that it does not hinder the flow of urine and it does not interfere with the operation of the scale. To this end, any portion of the tube between the pole and the Bosch profile structure must form a slightly negative angle with the horizon, to ensure that urine flows properly. However, at least in a portion of the tube, the angle must be small enough to prevent the transmission of forces from the bed of the patient towards the scale. An appropriate value for the angle formed by the tube and the horizon would be at least 5o at every point and, in at least a portion of the tube, the angle must be less than 10o to avoid force transmission.

The PGW 4502e scale is provided with a RS232 port. By sending a command to this port it is possible to obtain the scale reading. To avoid the need for wiring the scale to the PC that takes the readings, a serial-port-to-Bluetooth adapter is used. This allows us to take readings from any PC equipped with a Bluetooth interface. Also the Fuzzy set theory was used to process data and measure urine flow.

This concept presented an extended method of a prototype device that could measure a small amount of urine output date using an optical sensor placed in a medical dropper to record number of counted-drops[3]. The prototype was developed with multi-sensors, including photo interrupter sensor, infrared proximity sensor, and ultrasonic sensor, to detect the dripping and urine flow and real-time transferring data in to the cloud database. The final prototype is a combination of urine measurement using an optical method and weighted scale method. I this concept, HC-SR04 ultrasonic sensors were used in the prototype. They believed that a small amount of sound energy should be reflected by a dripping in front of the sensors and returned to the detectors. The receiver amplifier will send this reflected signal to a microcontroller which times them to determine how long it takes to receive the reflected wave, by using the speed of sound in air. For the prototype, the ultrasonic was initially designed to emit 40 kHz of sound waves to detect the crossing drops between the sound fields. This detection method will be started when ultrasonic transmitter emitted an ultrasonic wave in a one direction, and the starts timing when it launched. If the emitted sound wave detects the obstacles on the way, it would return immediately and the different attitude of the tension will be occurred in the receiver, and timer will stop timing when the sound waves returns from the reflection. The constant density of air is known as 1.2 kg.m-3 and the speed of sound in the air is around 343 m.s−1. The concept design is presented in Figure 7. The technique here is similarly to the bubbles detector devices. By using this methods, this device can be determined drop counts. The final prototype of this concept based on combination of the several optical sensors for detecting drop to calculated urine flow rate and its volume. Finally, the detected signal was sent through the amplifier circuit and after reduced signal noises. At the end the signal was sent to the central PC by using Bluetooth technology. Figure 8 shows prototype of the device.

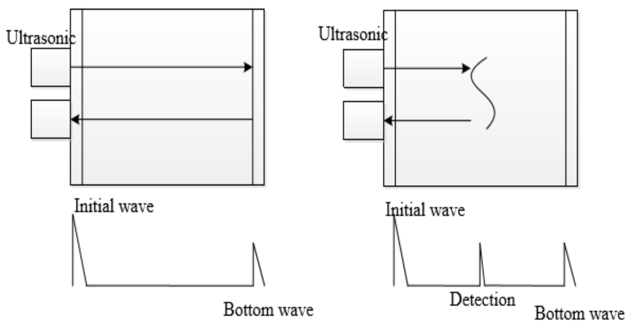

Figure 7: Detection concept diagram of ultrasonic pulse reflective technique

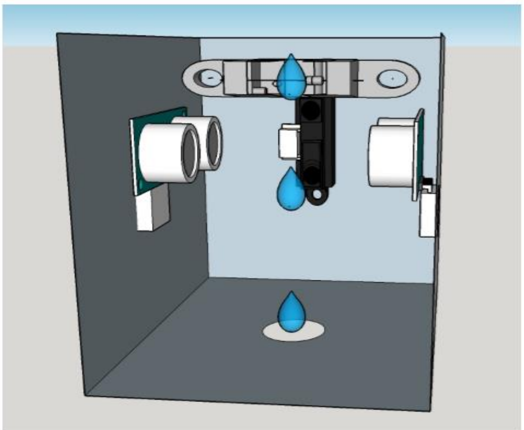

Figure 8: Prototype of the device

IV. CONCLUSION

In this paper, we discussed about different types of methods and different types of device that was used to measure the urine output of a patient. Also we discussed about suitability, weaknesses and using technologies of these concepts. According to these concepts, some of these concepts have high accuracy and some of them have low accuracy when comparing with practical situations.

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