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Accelerated Identification of Kidney failure via Exhaled Breath Biomarkers

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Abstract

Maintaining the body's ionic balance is the responsibility of the kidneys, which serve as the filter and disposal system for waste products. An ion imbalance in the body could indicate a kidney issue. It is advised to examine and monitor the kidneys to prevent kidney problems properly. The only two options left for a person suffering from kidney failure are kidney transplant surgery or at least three days of dialysis per week. For most Ethiopians, the cost of these two options is prohibitive. To solve this issue, a non-invasive, quick, portable, reasonably priced, and widely available homecare gadget that assesses kidney health is required. Ammonia has been studied as a biomarker to test the kidney's status in numerous studies on kidney detection, which have employed a variety of detection mechanisms. The kidney's function is evaluated by the device using breath ammonia. This approach involves taking samples from the patient, allowing the ammonia sensor to detect the concentration of ammonia in their breath. The value is then compared to the predetermined threshold, and if it is higher, the device alerts the patient to schedule a follow-up examination. A test was conducted in the ambient air, where the average standard concentration of ammonia in the air is 0.01-0.03 ppm and may increase in an enclosed area, to determine whether the prototype is functioning properly or not. A normal person's breath was used to test the prototype; this person's breath should always be below the 0.82 ppm threshold. The sample yielded a detected value of 0.29 ppm. One member of the group willingly provided this sample. The detected value from the device is sent to a developed mobile application via Bluetooth. The app analyzes the data and displays the kidney status of the patient. For patients who are illiterate in English, a voice message also be available as an optional feature. Eventually, the patient's phone storage will contain the ammonia concentration and the status, which can be accessed and shared across various platforms at any time. For the future it is batter to integrate AI and Use regression algorithm to provide more processed data.

Keywords:

Introduction

The kidneys are two reddish, bean-shaped organs on either side of the spine, beneath the ribs, and behind the stomach. The kidneys are located between the levels of the last thoracic and third lumbar vertebrae, a position where they are partially protected by the eleventh and twelfth pairs of ribs. The right kidney is positioned slightly lower than the left kidney. This is because the liver occupies considerable space on the right-side superior to the kidney. (Gerard J. Tortora, Bryan Derrickson, 2012) The two kidneys lie in the back of the abdominal wall but not actually in the abdominal cavity. They are retroperitoneal, meaning they are just

behind the peritoneum, the lining of this cavity. The urine flows from the kidneys through the ureters into the bladder, from which it is eliminated via the urethra. (Arthur Vander, James Sherman, and , Dorothy Luciano, 2001) The kidneys are important in maintaining the body's water and electrolyte balance, the acid-base balance, regulating the urine volume and composition, the blood volume, and producing vasoactive substances to regulate blood pressure and eliminate waste products from the blood. (K. W. Chung, 2005).

Blood filtering is the responsibility of the kidneys. The kidney filters blood plasma. Nutrients, essential ions, and water will be reabsorbed from and returned to the body. The remaining water and solutes constitute urine, which is then excreted from the body, eliminating metabolic waste products. Kidney disease is classified into two major parts. The first is an acute kidney injury (AKI), Acute kidney damage occurs when our kidneys cease working unexpectedly and for a short period. AKI is also known as acute renal failure or acute kidney failure. This happens due to a rapid increase in serum creatinine levels in the blood. The other is chronic kidney disease (CKD). Chronic kidney disease is a chronic ailment that occurs gradually due to malfunctioning or problems that are related to the filtration rate of the kidney. Kidney disease can be caused by different factors mostly due to the effect of other diseases. The diseases that act as a factor or cause of kidney disease are hypertension, diabetes, heart problems, etc. People with a history of kidney disease in the family may also have kidney disease. Tests for kidney disease can be done using a different technique. The main techniques that are used are blood test which is used to measure the amount of waste product present in the blood mainly creatinine and blood urea nitrogen, and urine test which is performed using a urine sample taken from the patient this test is used to check the presence of albumin protein, imaging test which is performed using imaging equipment's like ultrasound and CT-Scan to detect shape and location defects and kidney test can also be performed by taking a kidney biopsy directly from kidney which is used to identify how much damage has been made to the kidney. Glomerular filtration rate (GFR) is one of the major factors used to identify the functioning rate of the kidney. This determines how effectively the kidneys remove waste and extra fluid from the bloodstream. It's calculated by using the serum creatinine level and by considering the patient's age, body size, and gender. But nowadays several studies show that taking a sample of ammonia gas from the breath can also be used as a biomarker to identify the status of the kidney.

The treatment of kidneys includes two different methods. The first one is dialysis, which is performed 2-5 times a week based on the economy of the patient and this procedure is used to clean the waste materials aggregated in the blood of the patient. The other is the kidney transplant, which is performed when a matching donor is willing to give the kidney.

CKD is becoming more widespread over the world, with estimates ranging from 8% to 16%, and it is now recognized as a global public health issue (Allison J. Hahr and Mark E. Molitch, 2015). Only a few studies have looked into the prevalence of CKD among diabetic patients in Ethiopia. A study performed on individuals with diabetes in Butajira Hospital had a CKD prevalence of 18.2 percent to 23.8 percent (Fiseha T, Kassim M, Yemane T, 2014) and a similar hospital-based study performed in 2016 at Gondar University Hospital showed the overall prevalence of CKD as 21.8% (Alemu H, Hailu W, Adane A, 2020).

Chronic kidney disease (CKD) has been recognized as a leading public health problem worldwide. CKD is spreading over the world, with estimates ranging from 8-16%. Patients with end-stage kidney disease need renal replacement therapy. The main reason for the rise in CKD patients is that people have a poor habit of regular checks due to expensive testing procedures, not having routine checkups, time time-consuming, and minimally invasive ways of checking.

The main aim is to develop a simple home-use device that can indicate kidney abnormality using ammonia from exhaled air. A range of detection mechanisms have been used in numerous studies on kidney detection to investigate ammonia as a biomarker to assess the condition of the kidneys (Merel J. Lefferts., Martin R. Castell., 2022). The device uses breath ammonia to analyze the performance of the kidney. Noninvasive way of checking, users will be able to examine breath ammonia levels and monitor kidney health at home, users can have regular checkups with the designed device, users can track their kidney history, longitudinal follow up, can send test history to any health professional the provided app.

Method

The breath analysis method is the focus of this method. Because the kidneys' poor functioning causes high levels of ammonia in the breath of people with chronic kidney disease (CKD), the breath analyzer circuit uses ammonia gas sensors to perform the analysis. Both healthy individuals and those with chronic kidney disease provide breath samples into a tiny container. The samples are then sent to a MQ ammonia gas sensor, as seen in Fig. 1, which uses the sampled breath to identify ammonia and sends the concentration of ammonia gas to the controller overall. A variable resistor integrated into the sensor adjusts its value based on the amount of gas present. The resistance lowers at high concentrations. Resistance rises with decreasing concentration. The conductivity of the sensor increases with an increase in ammonia gas concentration, thereby reducing the resistance of the sensor. An output signal is generated by measuring and converting this change in resistance. The controller will process the value after receiving it via an analog or digital interface. After that, the outcome is displayed on the display board and compared to the threshold value. The ammonia gas threshold limit of the controller is defined by sating a normal person's ammonia level as less than 0.82 ppm and a CKD patient's ammonia level as greater than 0.82 PPM. After detection, the value of ammonia is sent to an Android phone using a Bluetooth module and the value sent to the Android device will be stored.

The system that was developed is made up of various subsystems that work together to accomplish the intended purpose. An MQ gas sensor, which measures the amount of ammonia in the breath sample, is the sensing mechanism used in this system. A microcontroller was utilized in this system to receive the sensor's output and format the value obtained from the gas sensor. The PPM of ammonia detected is calculated by the microcontroller, which then transmits this value to the output system. For the device to be connected to an Android device, a Bluetooth connection system is required. The app will receive the computed PPM value from the microcontroller via a Bluetooth module. The ammonia concentration is shown on an LCD and through a mobile application. The application that is required to display the ammonia concentration is installed and run on the mobile phone. Additionally, the application uses the phone's storage memory to store the daily ammonia concentration, which can be retrieved at a later time if necessary. The block diagram in Figure 1 illustrates how these subsystems are combined to create the intended system, which uses breath ammonia measurements to identify kidney disease.

Result

The average standard concentration of ammonia in the ambient air is 0.01-0.03 ppm, and it may rise in an enclosed space. This test was conducted to determine whether the prototype is functioning properly or not. The ammonia concentration standard value is utilized to verify the devices. In free air with temperature and humidity within the device-specified range, the average measured concentration using the devices is between 0.1 and 0.5 ppm. The device was tested using the breath of a normal person which always should be less than the threshold limit of 0.82 ppm. The device should detect the ammonia in the sample. The detected value from the sample is 0.29 ppm. This sample was taken from one of the group members voluntarily.

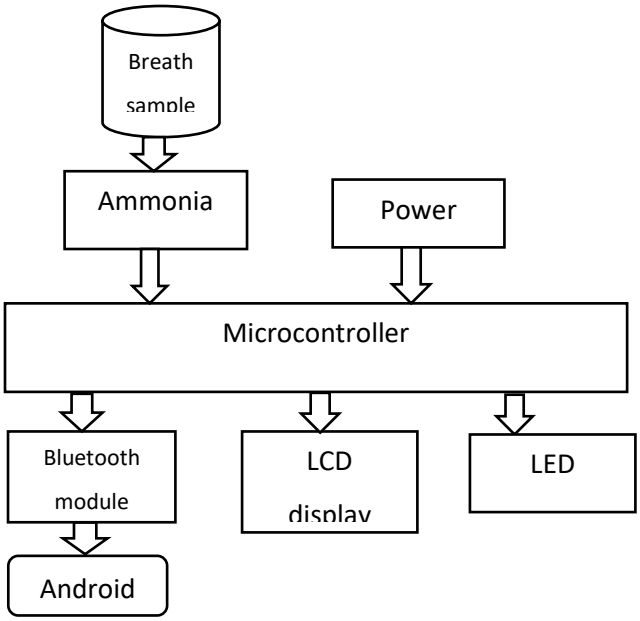

Figure 1: Block diagram of the system

The rise in the number of CKD patients in our country is because people have a poor habit of going to the doctor regularly, and they only go to the hospital when they have a serious illness. This is due to a variety of factors, including unfair and expensive tests, equipment needed for regular tests are expensive and due to this, some healthcare sectors don't have the equipment, long wait times for service, and people's inability to afford the services provided by hospitals, so regular checkups are seen as a sign of wealth. Assessing these problems, the design team came up with an idea to provide a device that could eliminate these major difficulties that prevent people from having regular checkups.

Compared to the devices that are in use these days the designed device is affordable to any healthcare sector and also it can be afforded to several individuals the device can be used as a home care device and people can use it to get a daily checkup and save their daily information in the storage provided by mobile application and can share the saved information with a health professional when needed. Also, the designed device is lightweight and portable which makes it more suitable for home care.

Discussion

The devices on the market are focused on healthcare organizations because they require the presence of specific medical professionals to operate; however, these devices are also meant to be used independently, allowing consumers to purchase and utilize them at home.

The creatinine test results take approximately 30 minutes to come back from the time-wise devices that are currently in use. This is because the serum must be extracted from the whole blood. However, patients can view their results in a matter of seconds with this device.

Due to the fact that the Android application is designed to enable users to view results on their phone and store them in phone storage, this design also offers extra features for smartphone users. When a history of the patient's kidney condition is needed, the saved file can be shared with physicians.

Conclusion

In the twenty-first century, chronic kidney disease presents a significant challenge to international health policy. In developing nations, the increased occurrence of long-term illnesses like chronic kidney disease has detrimental effects on both health and the economy. Developing nations such as Ethiopia urgently need more advanced and reasonably priced kidney disease diagnostic devices.

Therefore, the goal of this project was to develop a device that people could afford and use at home without the help of a professional, enabling them to receive a quick checkup in a matter of minutes. Kidney abnormalities are intended to be detected by the device. The apparatus measures the amount of ammonia in the breath sample that the user provides. Next, the outcome is contrasted with the ammonia threshold of 0.82 PPM. For values below the threshold, the device displays a "normal" message; for values above the threshold, it displays a "Get Checkup" message to assess the need for additional diagnosis. The periodic checking of the kidneys is difficult because the tests are expensive and the tests require around 30 minutes to get and the long wait to get those results is frustrating. In approaching this gap this project sought to use the ammonia that is being exhaled as a means to design a home care device. This homecare device is cost-effective, portable, and durable, as a result, users can check the status of their kidneys in the comfort of their homes. In addition, the status can be stored on their smartphones and the results are notified using sound interfaces. If this device gets manufactured and introduced to markets, the culture of getting routine kidney checkups will be improved. Furthermore, lives that might be lost because of kidney failure could be saved.

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