Self – Operative Creatinine Test Kit

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Abstract

The stand-alone creatinine test kit design is home care monitoring technology, i.e., patients at risk of kidney injury or chronic kidney disease (CKD). The new kit enables individuals to self-calculate their own creatinine levels better and more precisely without necessarily utilizing the services of well-trained professional health care providers. The primary intention of this kit is to reduce the need for professional medical care to the utmost level, thus emulating an automated process. The test kit is provided with a simple, easy-to-handle system, including a urine sample collection device and colorimetric assay for the determination of creatinine. It can provide results in a few minutes with instant feedback on kidney function. The self-testing creatinine kit aims to ensure patient autonomy and allow for the early detection of kidney disorders, thus facilitating early medical care. The kit has been prepared for use by common patients who are far from hospitals or do not have easy access to hospitals.

Keywords: Self-Operative, CKD, Creatinine Levels, Colorimetric Assay, User-Friendly.

1. Introduction

Chronic kidney disease (CKD) is a progressive disease characterized by nephron loss a reduction in glomerular filtration rate (GFR) resulting in the diminishment of renal function. The urinary creatinine test is a significant method used to estimate renal function by measuring the quantity of creatinine, the end product of muscle metabolism, excreted by normal kidneys. Kidney malfunction in CKD leads to increased serum levels of creatinine and its abnormally

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cleared portion in the urine. This biomarker is extremely vital in assessing disease progression, identifying renal insufficiency, and adjusting treatment protocols. Diagnostic procedures are, however, currently entire dependent on advanced equipment and highly trained staff, making them unsuitable for home or point-of-care (POC) testing on a daily basis.

Paying attention to this, the present paper proposes an innovative, artificial intelligence-based, self-use creatinine test kit that would allow patients and healthcare providers to screen renal function easily and simply at home. While accurate information from laboratory-based creatinine testing techniques, such as high-performance liquid chromatography (HPLC) and enzymatic assays, is very expensive and not practical for mass, real-time quantification, the current POC devices used for determining creatinine which include reagent strip-based and portable analyzer-based devices are not standalone and require calibration often at the expense of precision and convenience. These devices function based on visible colorimetric change or optical sensors, which have the potential to provide false results.

There is therefore a crying need for a cheap, handy test kit that will provide accurate and timely creatinine results, particularly for patients with chronic kidney disease who are often in need of repeated tests.Our laboratory creatinine test kit employs innovative artificial intelligence (AI) technologies in an effort to overcome the limitations of conventional approaches. The unique AI features are:

1. Automatic Data Calibration and Normalization: The AI app is integrated into the test kit so that it provides accurate and reliable results in the future. It learns users' past readings, self-calibrates, and optimizes to lab-provided readings. This provides high accuracy with minimal user recalculation.

2. Ease-of-Use Interface and Guidance: With voice and visual interfaces are accessed through AI, the kit provides immediate guidance on testing. The AI system also offers step-by-step instructions so that non-medically qualified individuals can successfully conduct the test. It also gives feedback regarding whether the test has been conducted, improving the user interface and reducing the scope of errors.

3. Predictive Analytics for Disease Progression: The package delivers predictive modeling using artificial intelligence to monitor creatinine levels over time. The AI will forecastpotential disease progression or remission from data patterns. This

functionality would be most valuable for CKD patients because it would allow monitoring of declining kidney function and earlier treatment.

4. Cloud Storage and Integration of Data: The test kit integrates with cloud infrastructure, allowing users to remotely store and see their creatinine data. Algorithms based on artificial intelligence monitor this data for some time, which aligns with individual health trend, and enabling it to be shared with healthcare providers. Cloud integration facilitates real-time monitoring, allowing for early detection of health issues and improved patient care.
5. AI-Supported Diagnostic Guidance: The AI system can integrate information from other wearables, such as blood glucose or blood pressure monitors, to generate a holistic health profile of the user. AI is capable of providing personalized guidance based on the interaction between these variables and creatinine levels, enhancing the overall management of CKD patients.

2. Literature Review

More recent advances in the field of kidney function tests and urinary biomarkers have enhanced the detection of early diseases, risk stratification, and monitoring of patients markedly. Park et al. [1] discussed the use of urinary creatinine concentration and color of urine as markers in specimen validity testing, highlighting their ease of use and accuracy in routine screening. Within the preoperative setting, Prowle et al. [2] compared cystatin C and creatinine in a comparative analysis and concluded that cystatin C could provide greater sensitivity in the detection of patients at risk of post-operative acute kidney injury. In addition to this, Demirjian et al. [3] created a laboratory-predictive model for perioperative AKI that incorporates several biochemical parameters, refining pre-surgical risk stratification.

In this context, Gao et al. [4] proved the efficacy of self-expanding metal ureteral stents in reducing ureteral stenosis in broad clinical trials, suggesting a minimally invasive option in recurrent cases in a subsequent investigation by the same team [5]. Jakubowski et al. [6] tested the effectiveness of self-testing for proteinuria in hypertensive pregnancies, confirming the utility of domestic diagnostics in monitoring maternal health.

Point-of-care technologies have also appeared strongly. Lewińska et al. [7] constructed a paper-based colorimetric creatinine sensor for urine that is compatible with smartphone technology, enabling portability and simplicity. Likewise, Diforti et al. [8] presented a graphene lab-on-a-chip system for noninvasive, multiplex kidney biomarker analysis, opening the door for self-directed digital diagnostics.

Other research expanded creatinine analysis to larger clinical areas. Olarinoye et al. [9] applied creatinine estimation within a comparative diagnostic approach to premature rupture of membranes, facilitating improved obstetric decision-making. Lin et al. [10][11] critically reviewed the diagnostic ability of serum creatinine and cystatin C-derived indices for sarcopenia, uncovering their joint potential in detecting muscle-wasting disorders in older populations. Furthermore, Okubo et al. [12] found that the creatinine-to-cystatin C ratio could reflect postoperative functional outcomes in older hip fracture patients, demonstrating its relevance in geriatric rehabilitation planning.

3. Proposed Work

The proposed system is an inexpensive, compact, and automated system for creatinine concentration detection in urine. The proposed system employs an Arduino Uno microcontroller, a Near-Infrared (NIR) spectroscopy sensor, and Bluetooth-controlled pumps for reagent dispensing, sample manipulation, and analysis. The entire process of mixing urine and reagent, analyzing the sample by NIR, finding the concentration of creatinine, and showing the result on an LCD display will be automated by the system. It even has an in-built self-cleaning system for sterilization of the system between tests to prevent cross-contamination.

A. System Design and Components

Each component of the system is an important part of capturing, processing, and displaying real-time information:

- **Arduino UNO Microcontroller**

Arduino Uno is a controller and is a master controller utilized to effectively process the data from sensors in automation projects. Due to its versatility, it can be utilized to control motors, LEDs, and relays among other parts based on sensor information. Arduino Uno, being minimalist with an extensive library, is best suited for creating interactive systems as well as for prototyping.

- **LCD Display**

The LCD screen provides instant feedback to the user in the form of messages such as "Monitoring Active", "Irregularity Detected", or "System Error". The users can track the ongoing creatinine values and are alerted to any irregularities.

- **NIR Sensor**

The NIR sensor tracks a sample mixture's absorbance and provides results that are relatable to the concentration of creatinine. The non-invasive property facilitates easy monitoring of biochemical properties, widely applied in medical and sdiagnostic purposes.

- **Solenoid Valve**

The solenoid valve properly controls liquid flow accurately for sample delivery to the analysis container. It opens and shuts according to electrical instructions, providing high-precision fluid control. It minimizes spillage, contamination, or measurement error potential. It makes the system more accurate and reliable by automating fluid control. Its rugged design and high response rate make it lab and industrially safe to operate.

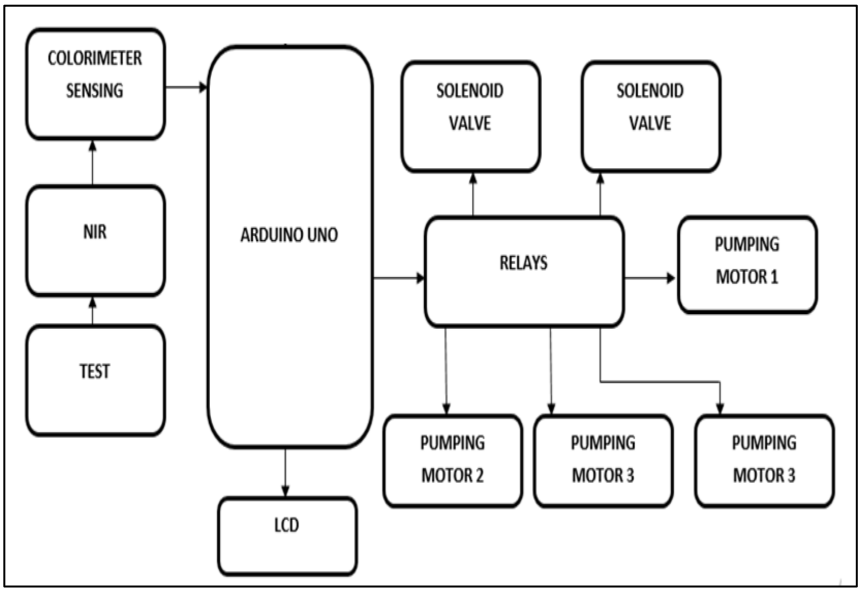

Figure 1. Bock Diagram of Proposed System

- **Single Relay Board**

A single relay board can be used to switch high-power devices with low-power microcontroller signals, such as those from the Arduino. It is one type of electrical switch that allows for the controlled operation of pumps or motors. The relay shields the microcontroller from high voltage and protects the circuit. With a low footprint and easy interfacing, it is used in home control and automation tasks. Its straightforward installation makes it a good solution for repurposing.

- **Power Supply**

The power supply stable power for the components of the system. It implements a standard 12V DC power for Arduino UNO and a 5V power for the sensors, amplifiers, and AI microcontrollers, offering all components their required voltage range.

B. Software Requirements

The system utilizes specific software tools and programming languages to operate successfully and analyze data in real-time:

- **Arduino IDE**

The Arduino IDE is used for programming and uploading the program to the Arduino UNO. The program handles data reading from the sensors, processes the ECG and heart sound data, manages feedback loops, and triggering alarms.

Embedded C++ is used to implement the system, generating low-level and efficient code to drive the hardware and process real-time sensor data.

C. Control Logic Implementation

The unit operates consistently to track urine creatinine levels, with the purpose of detecting abnormalities and providing instant feedback to the user.

The integration of a Near Infrared (NIR) sensor into an Arduino Uno microcontroller allows for the quantification of creatinine concentration in urine samples. The NIR sensor detects the reflection and absorption characteristics of the sample in the near-infrared range, enabling precise and non-invasive determination of creatinine levels. The Arduino Uno serves as the processing board, reading data from the NIR sensor and converting analog signals to digital values.

For easy user interaction, the Arduino Uno is equipped with an interfaced LCD display module. The LCD is designed to display the measured real-time creatinine concentration. An

LCD interface is utilized to provide a simple, readable, and interpretable presentation of the data, making it an effective and user-friendly device for use in laboratory and clinical settings. Synchronization between the sensor, Arduino Uno, and LCD display is facilitated through tailored software to enable seamless data transmission.

D. Safety Mechanisms and Considerations

For patient safety and reliable diagnostic performance, the system utilizes various inbuilt safety mechanisms.

Sample volume detection sensors prevent inappropriate results by alerting users in the event of low sample volumes. Reagent storage and expiration reminders alert users via voice or visual notifications when reagents expire or are stored inappropriately. There is a built-in self-calibration system to provide consistency of results to laboratory standards by automatically modulating system parameters. Test kit batches undergo rigorous quality testing and calibration to clinical-grade levels of accuracy. There is even an internal sterilizing pump that can be used for between-use internal cleaning prevent cross-contamination hazards. Lastly, all parts in contact with reagents or urine are constructed from strong, non-toxic medical-grade substances such as stainless steel and biocompatible plastic, and thorough material compatibility testing is conducted to prevent chemical leaching and provide long-term safety.

4. Result

Prototype production and field deployment of the autonomous creatinine testing kit were successful in demonstrating its ability to be a useful home health monitoring device. The system, constructed using an Arduino Uno microcontroller, utilizes several components such as colorimetric sensing, near-infrared (NIR) sensing, solenoid valves, relays, and pumping motors to automate the procedure of creatinine testing. Utilizing an LCD display offers the functionality of the test result being visually observed by users in real time.

The prototype of the test kit was correctly validated to assess its usability, reliability, and accuracy. The colorimetric sensing module provided consistent values of creatinine concentration through the chemical reaction of the test sample. The solenoid valve and pumping motor-driven system that constituted the fluid handling system ensured efficient dispersion of the reagent for producing precise and consistent test results. The processing unit used was the Arduino Uno, which was assigned the duty of efficiently processing sensor data, motor control, and display output.

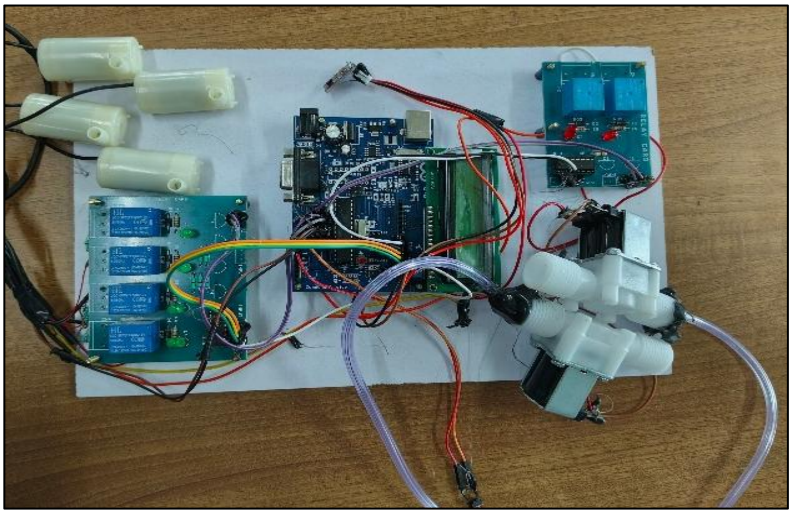

Figure 2. Overall Connections of the Kit

Experimental results indicated that the self-testing kit produced creatinine level test results similar to those obtained from standard laboratory testing procedures. The system's fast speed allowed for the provision of test results within minutes a notable time savings compared to traditional diagnostic tests. The AI functionality of the kit also reduced the technical skills required, making it highly recommended by non-technical groups, such as rural or disadvantaged communities.

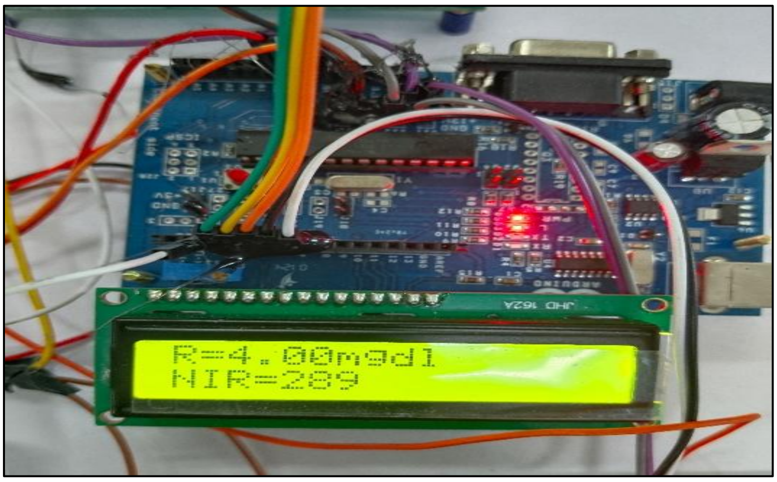

Figure 3. User Interface

The advantages of the system are increased access, lower costs, and the ability to perform multiple screenings without the aid of qualified medical personnel. The product empowers individuals to be self-sufficient in getting screened for their kidney disease, enabling early detection and prompt medical care if required. Its successful implementation demands future innovation, i.e., inclusion of wireless connectivity as a measure to remotely transmit results and increase sensitivity for obtaining more precise results.

5. Conclusion

The device functions adequately to define an innovative automated creatinine analyzer in urine using an Arduino Uno microcontroller, NIR-based calorimeter sensor, and Bluetooth-controlled reagent dispensing for the provision of reproducible and accurate output.The device functions adequately in fusing advanced sensing technology and automated reagent dispensing to enable diagnostic accuracy with minimal human involvement.

Facilitating automation of the key steps of reagent mixing, sample incubation, and absorbance measurement, the device provides high reproducibility, making it the ideal platform for point-of-care diagnosis. Having a mathematical model for the analysis of NIR absorbance measurements as a function of creatinine concentration also adds strength and clinical utility to the results. Bluetooth control and an LCD display enhance the user interface through remote control and instantaneous result interpretation.Such benefits are further enhanced with higher system workability and ease of use, especially for new users, when optimizing operational effectiveness.

The value of providing an automatic sterilizing pump for after-each-test-cycle cleaning enables hygienic operation and reduces the risk of cross-contamination, thus optimizing operational reliability and safety for a vast array of applications. Miniaturization of the system and cost-effectiveness for acquisition also contribute to its portability and scalability, addressing the demand for low-cost diagnostic devices in resource-limited settings. The project represents a significant innovation in point-of-care diagnostics by offering a cost-effective, handheld, and efficient mode of renal function monitoring. The robotic features of the system, along with high precision and convenience, make it more appealing than traditional laboratory creatinine measurement. The development of NIR sensing algorithms, integration of the recording function, and expansion of major biomarkers quantifiable by the system are some of the directions in which it will continue, and in which it can currently be used as a general-purpose medical diagnostic machine.

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