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Short Literature Review on Diagnosis of CKD using Gas Sensors

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Abstract: ***According to the recent survey, Chronic Kidney Disease (CKD), Hypertension, Diabetes Mellitus type I & II are very common among the people now a days. The portable and user friendly devices like sphygmomanometer, Glucometer are developed for the diagnosis of Blood pressure (BP) and blood glucose respectively, which are available commercially. This literature review focuses on the development of portable CKD diagnosis system using different types of gas sensors. The Ammonia is marked as the major biomarker in the diagnosis of any kidney disease, the presence of elevated concentration of ammonia in the breath of a person reflects any kidney problem in the body. This Ammonia and other gases which constitute the kidney problem like Nitrogen oxide which acts as the biomarker for end stage acute kidney disorder are diagnosed with the help of several gas sensors like Ammonia gas sensor, Gold Nano particles sensors, Nano composites sensors etc., It is possible to develop a system for the diagnosis of CKD using the gas sensors which could reduce the time consuming regular clinical diagnosis of the same.***

Keywords: CKD, Ammonia Sensor, GNP sensors, portable device, Gas sensing, Nano composites, Biomarkers.

I. INTRODUCTION

Kidney plays vital role in the human body, the main function of the kidney is to remove the possible metabolic wastes, foreign chemicals that is either injected or produced due to the metabolic activity within the system. It also has control over the composition of the body fluids and does several functions that enhance orientation of the proper body regulations and functions [1]. Such Kidney is said to be malfunctioning when it loses its ability to filter the metabolic waste from the blood which is generally known as Kidney failure. The Kidney disorder can be broadly classified in to five different types they are acute pre-renal Kidney failure, Acute Intrinsic Kidney failure, chronic pre-renal Kidney failure, Chronic Intrinsic Kidney failure, chronic post-renal kidney failure [2]. This literature review focuses on the diagnosis of the chronic kidney disease using the gas sensors. The chronic kidney disease is the initial stage of the kidney damage which leads to kidney failure if left untreated. The main causes of this kidney diseases is due to many reasons such as infections, blood clot in kidney, consumption of alcohol and drugs, severe diabetic condition, high blood pressure and exposure to chemical pollutions. Some of the common symptoms of CKD are muscle cramps, feet inflammation, itching, nausea o vomiting etc. [3].

The estimation of chronic kidney disease in India is more than 1 million cases and globally stage 3 (majority stage) CKD is estimated as 11 to 13 percentages [4]. Several clinical diagnosis methods are done according to the patient categorized discussed below, since these clinical methodologies are laboratory based and consumes time and energy, the alternative diagnosis methods that could be used for the diagnosis of CKD are discussed in following.

1.1 Volatile Organic Compounds (VOC) and CKD:

This progressive chronic kidney disease can be diagnosed using the volatile organic compounds called as VOC from the exhaled human breathe. The VOC in the breath gives various information regarding the influence of disease, metabolic and physiological activity in a human body; precisely this VOC's can be called as the biomarkers for the different types of diseases present the human body. The main components that are present in the exhaled human breath are Co2, nitrogen, hydrogen gas and water vapors. And the components present in the breath can be divided into organic and inorganic compounds, where inorganic compound comprises of nitrous oxide, CO, ammonia and organic compound comprises of ethane, acetone, isoprene etc [7, 20]. The Ammonia that is present in the body possess special nutritional values which helps in the maintaining the acid base balance and metabolic activity in the human body, resulting in the production of the non-essential excess amino acids. This excess waste and the resultant of the metabolic activity are excreted via urine and sweat. If this cycle of removal is disturbed, it is reflected in the human breath. The ammonia concentration for the normal human individual is 250 parts per billion. When the ammonia level in the breath elevates, then that individual is subjected to have kidney problem [7].

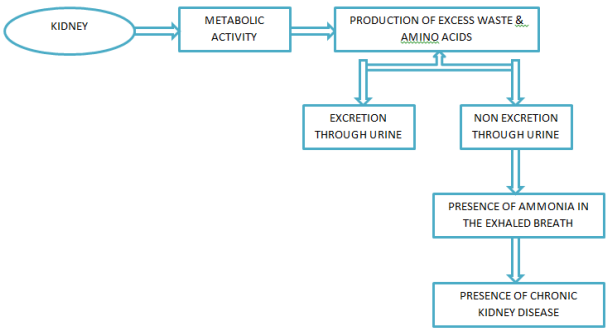

Fig 1.1.1 block diagram representing the relationship between ammonia gas and CKD

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II. DIAGNOSIS OF CKD

The most common methods for the diagnosis of chronic kidney disease can be categorized according to the symptoms an individual have.

An individual who has high blood pressure, diabetes, CVD, kidney stones, protein or blood in urine are recommended for the regular test procedures.

Some of the common diagnosis procedure for the CKD is blood test, urine test, and other tests such as ultrasound scan, CT or MRI scan, kidney biopsy [5].

Usually, eGFR that is estimated glomerular filtration rate is used to measure the level of performance of the kidney function and diagnosing the stage of the kidney disease. When an individual is said to have the eGFR level as less than 15%, then he is subjected to kidney failure.

The kidney problem starts with the GFR level of <89 % [6].

The following flow chart fig 2.1 gives the screening and diagnosis of chronic kidney disease [8].

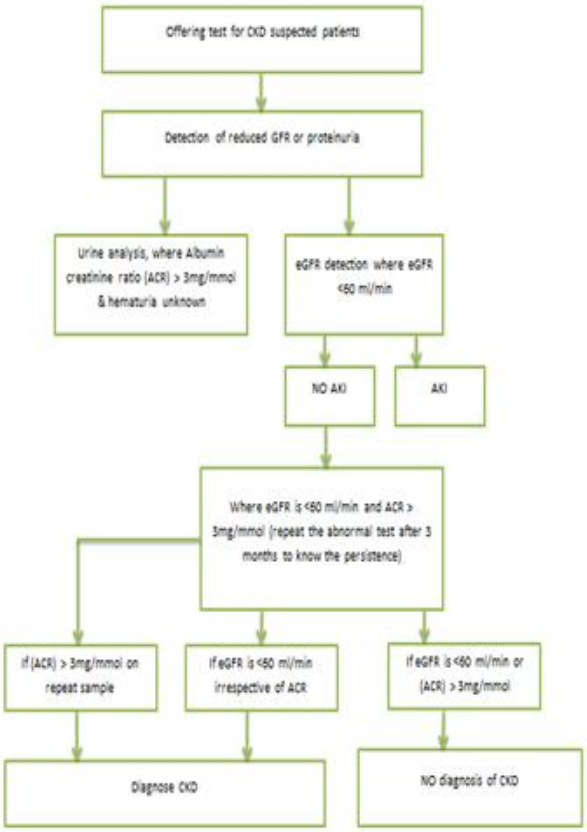

Fig 2.1 General diagnosis method of CKD using ACR and eGFR

III. TREATMENT FOR CKD

The CKD doesn't have actual cure for the chronic kidney disease, but the damage that is caused in the kidney can be treated with some medications.

The treatment given to the patient is usually based on the means of the causes the individual experienced.

If these kidney complications caused is left untreated it will lead to the acute kidney failure (end stage), which is treated either by dialysis or kidney transplants [19].

In the following different literature review, the usage of the gas sensors for the diagnosis of chronic kidney diseases is explained in brief.

IV. DIAGNOSIS OF CKD USING GAS SENSORS

4.1 Exhaled breath analysis using electronic nose and gas sensor

Tarik Saidi, omar zaim, Mohammed Moufid et al, proposed a research paper where the chronic kidney disorder, diabetes mellitus are diagnosed using a system known as e-Nose, here in this method the exhaled breathe is analyzed with respect to the VOC's that are responsible for the kidney disorder and diabetes mellitus.

The results obtained from testing this e-Nose with the patients are verified and tabulated with the test results that are obtained from the urine tests acquired using the spectrophotometer. This e-Nose is built with commercially available six different types of gas sensors that are used for the diagnosis of specific disease or disorder, for example, MQ 135 is used for detecting the presence of ammonia, nitrous oxide, Co2 and benzene in the exhaled breath which in turn gives the result of diagnosis of CKD in an individual, likewise MQ 138 gas sensor is used for the diagnosis of diabetes mellitus because this gas sensor provides the presence of acetone, formaldehyde which acts as the biomarker for diabetes mellitus type I & II. Finally, the results are analyzed and classified using the different types of classifiers [9].

4.2 Breath Ammonia Analysis Using polyaniline Nano-Composites Sensors and e-Nose for CKD Diagnosis

Paul Le Maout, Jean-Luc Wojkiewicz, Nathalie Redon et al, have proposed a portable device for the diagnostic purpose of CKD, here in this paper it was discussed about the eleven specific types of polyaniline Nano-composites. The general idea behind using these Nano-composites for the ammonia level prediction is based on the principle of e-Nose. These selected polyaniline Nano-composites were based on chitosan, carbon nanotubes.

Even small changes in the concentration of ammonia in a typical human breath can be sensed and maximum variations of certain values were detected and diagnosed. This paper also states about the problems like sensor failure, drift and also highlights about designing the Nano composite sensor based on e-Nose technology which is highly helpful in detection of ammonia in high efficiency [10].

4.3 CKD Diagnosis Using Gold Nano Particles

Ophir Marom, Farid Nahout, Ulrike Tisch et al, proposed a research paper on diagnosis of initial stage of chronic kidney disease and the progression of CKD stages using the gold Nano particles, this idea is proposed because it is said to be the cost effective procedure in a portable system.

This research paper proposes breath analysis using two or three different combination of the gold Nano particles which is specifically selected from 20 different GNP sensors. These GNP sensors are said to be chemiresistive which is developed under certain procedure, this CKD responses obtained from the GNP is actually obtained by applying SVM analysis for the statistical pattern analysis [11].

4.4 Breath Analysis and deuterated water vapor in CKD

Simon J davies, Patrik spanel, David smith, proposed a system that could predict the potential traces of the concentration of the organic volatile compounds like ammonia, isoprene ethane which unlike other systems of diagnosis, it also helps in the diagnosis of tissue injury. The ammonia acts as the biomarker for the chronic kidney disorder like renal failure and isoprene, pentane acts as the biomarkers for the tissue damage in kidney, which in turn represents the kidney injury. This kidney injury can be caused due to the dialysis treatment itself, so development of such device is very much helpful in monitoring the patient who is under the dialysis treatment. By injecting the deuterated water into the dialysis patient, the serious complications at the 5^{th} stage of CKD, over hydration can be diagnosed from the water vapor that is exhaled from the respective patient. The different techniques are practiced and reviewed for obtaining the better results in diagnosis of CKD and kidney injury, where the sensors like nanoparticle sensors and carbon nanotubes are used here; these predict the presence of ammonia and VOC [12].

4.5 Clinical Diagnosis Using Expired Human Breath

Thalakkotur Lazar Mathew et al, has explained about the different types of clinical diagnosis that is used in analyzing the exhaled human breath. Here the various techniques that could help in the portable, easy diagnosis of CKD can be obtained. The ammonia is used as the biomarker and the metabolism which gives the relationship between the ammonia and CKD diagnosis is given. All the clinical techniques like gas chromatography, GC-MS etc., are reviewed with the Nano-sensors, gas sensors and tabulated the efficiency of diagnosis respectively [13].

4.6 Assessment of "Breath Print" In CKD during Dialysis Using E-Nose

Omar zaim et al, have proposed system for diagnosis of CKD during hemodialysis. For this procedure the system is coupled with e nose that is based on Sno2 sensors and PCA, SVM for resolving the complex classification situations. The bag that is connected to the array of commercially available gas sensors which is based on the Sno2 sensor is used for the acquisition which is leads for the diagnosis an further classification of the CKD of Hemodialysis [14].

4.7 Detection of kidney failure by halitosis

Nikitha Rajendran et al, have discussed about the development of the prototype for the diagnosis of acute kidney disorder and chronic kidney disorder by the halitosis (Bad breath). Here in this prototype, the ammonia sensor is used to acquire the ammonia concentration from the exhaled breath of an individual. This is performed under two different cases of dialysis patient with hypertension and dialysis patient with hypertension and tabulated. When the individual with >300ppb ammonia in breath is identified then that individual is suspected to have the kidney disorder [15].

4.8 Breath ammonia detection for CKD diagnosis

Sebastjan Bevc et al, have performed the chronic kidney diagnosis with the usual method of determining the serum Cretenine and estimating the glomeruli filtration rate. This is observed for the reference or cross verification. In this paper they have used gas analyzer with gas mixing device controlled by the statistical computer software SPSS 18.0.0. The average of healthy and CKD individuals were calculated and tabulated in the result and efficiency of using ammonia detection in breath for CKD is also observed [16].

4.9 Bio & chemical sensor for monitoring CKD

Antonio tricoli et al, have discussed about the point of care sensing device which utilize bio and chemical sensors for the diagnosis of CKD that is present in Sweat. The non-excreted metabolic waste such as excess amino acids, nitrogen are present in the body fluids like sweat, urea, which acts as the biomarker for CKD. It comprises of two modes of iontophoresis and sensing, which is built with the sensor electrodes for sensing the sodium and chloride ions that is present in the sweat, this helps in the diagnosis of urea in sweat and same breath sample analysis is done for ammonia sensor using the highly sensitive gas sensors (disposable NH3 sensors, comprising of PANI Nanoparticles). And this is used for the analysis of ammonia concentration based on pre and post dialysis cases and tabulated [17].

4.10 Analysis of Creatinine Exhaled breath and CKD diagnosis

Qian Zeng et al, have proposed a research paper on the detection of creatinine in the breath samples by developing a novel platform of EESI-MS, which is abbreviated as extractive electrospray ionization mass spectroscopy. The CRE and methanol are used in this EESI platform and the experiments are done in the mass spectroscopy, samples comprising of standard creatinine solutions and gas phase sample of creatinine were prepared for cross verification and calculation. After the complete fabrication of this novel system, the testing is done with the patient undergoing pre and post dialysis [18].

V. FUTURE SCOPE

The chronic kidney disorder and diabetes are now common problems among the people. This chronic kidney disorder is not fatal until it is treated at the initial stage of the problem. The main factor that causes the kidney disorder is blood pressure. When the blood pressure of an individual increases beyond the normal level, the glomeruli of the kidney experience the pressure, which in- turn pave way for the renal failure. So this CKD can be diagnosed with the help of human breath exhaling VOC, in which the presence of ammonia, potassium, and acetone are present. And as an extension of using the gas sensor for diagnosis of kidney failure, it is also studied that the gases like isoprene can also be used for the diagnosis of Type I&II diabetes mellitus.

This future scope mainly focuses on the smart wearable system specially designed for any worker who uses mask and gloves as part of their working suit like coal miners. A recent study shows that the coal miners undergo Both CKD and AKD, where CKD is not fatal and AKD is fatal.

The more number of cases were registered in CKD for the men in the age group of 38±5 and they were also subjected to hypertension. So the measurement of blood pressure and gas (ammonia and acetone) levels can give the report of the workers daily which would be useful for an individual to check and keep track on their health periodically.

VI. CONCLUSION

According to the recent survey of chronic illness, CKD are due to pollution, work stress etc. Since the kidney failure here is chronic, the continuous monitoring of the workers can help themselves preventing from the advanced stage of chronic renal failure by taking essential measures. By designing a wearable system on the basis of the diagnosis of CKD and AKD, Diabetes mellitus by sensing ammonia, acetone level from the breath could be helpful in monitoring own self on daily basis.

REFERENCES

1. Guyton & Hall, "Medical physiology", 12th Edition, Elsevier Saunders, 2010.
2. https://www.healthline.com/health/kidney-failure#types/recently updated(May 23 2019)
3. https://www.kidneyfund.org/kidney-disease/kidnay-problems/recently updated (June 17 2020)
4. Nathan R. Hill, Samuel T. Fatoba […..] and F.D. Richard Hobbs, "Global prevalence of chronic kidney disease-A systemic review and meta-analysis" journal. pone, July 6 2016.
5. https://www.nhs.uk/conditions/kidney-disease/diagnosis/chronic/recently updated (29august 2019).
6. https://www.kidney.org/atoz/content/gfr/ recently updated, 2019.
7. Sagnik Das and Mrinal Palz, "Review—Non-Invasive Monitoring of Human Health by Exhaled Breath Analysis: A Comprehensive Review", Journal of electrochemical society, vol-167, 2020
8. https://tam.nhsh.scot/home/therapeutic-guidelines/renal-disorders/screening-and-diagnosis-of-chronic-kidney-disease-ckd/ recently updated, 2019
9. Tarik saidi, omar zaim, mohammed moufid, Nezha El bari, Radu lonescu, benachir Bouchikhi, "Exhaled breath analysis using electronic nose and gas chromatography–mass spectrometry for non-invasive diagnosis of chronic kidney disease, diabetes mellitus and healthy subjects", Science Direct, vol 257, ph-178-188, March 2018.
10. Le Maout P, Wojkiewicz J-Luc, Redon N, Lahuec C, Seguin F, Dupont L, Mikhaylov S, Noskov Y, Ogurtsov N, Pud A, "Polyaniline Nano composites based sensor array for breath ammonia analysis. Portable e-nose approach to noninvasive diagnosis of chronic kidney disease", Sensors and amp; Actuators: B. Chemical (2018).
11. Ophir Marom, Farid Nahout, Ulrike Tisch, Ala shiban, zaid abassi, Hossam Haick, "Gold nanoparticle sensors for detecting chronic kidney disease and disease progression", Future medicine-Nano medicine, vol- 7, pg- 639-650, 2012.
12. Simon J davies, Patrik spanel, David smith, "Breath analysis of ammonia, volatile organic compounds and deuterated water vapor in chronic kidney disease and during dialysis", Journal of Bio Analysis, vol-6, pg- 843-857, April 2014.
13. Thalakkotur Lazar Mathew, Prabhahari Pownraj, Sukhananazerin Abdulla, Biji Pullithadathil, "Technologies for Clinical Diagnosis Using Expired Human Breath Analysis", Journal of diagnostics,vol-5, pg-27-60, August 2014.
14. Omar zaim, Tarik Saidi, Nezha el Bari, Benachir bouchiki, "Assessment Of "Breath Print" In Patients With Chronic Kidney Disease During Dialysis By Non-Invasive Breath Screening Of Exhaled Volatile Compounds Using An Electronic Nose", IEEE international symposium on olfaction and electronic nose (ISOEN), September 2019.
15. Nihitha Rajendran, Vinupritha.P, "Design of a prototype system to determine ammonia concentration in exhaled human breath in the diagnosis of kidney failure", Indian journal of public health research & development, Vol- 10, issue-7, pg-1292-1296, 2019.
16. Sebastjan Bevc, Eva Mohorko, Mitja Kolar, Polona Brglez [….],Radovan Hojs, "Measurement of breath ammonia for detection of patients with chronic kidney disease", Journal of clinical nephrology, vol-88, pg-14-17,2017.
17. Antonio Tricoli, Giovanni Neri, "Miniaturized Bio-and Chemical-Sensors for Point-of-Care Monitoring of Chronic Kidney Diseases", Journal of sensors, Vol-18, Issue-4, pg-942, March 2018.
18. Qian Zeng, Penghui Li, Yunfeng Cai, Wei Zhou1, Haidong Wang, Jiao Luo, Jianhua Ding and Huanwen Chen, "Detection of creatinine in exhaled breath of humans with chronic kidney disease by extractive electrospray ionization mass spectrometry", Journal of breath research, Vol-10, issue-1, Feb 2016.
19. https://www.mayoclinic.org/diseases-conditions/chronic-kidney-disease/diagnosis-treatment/recently updated_2020
20. L. Blanchet, A. Smolinska, A. Baranska, E. Tigchelaar, M. Swertz, A. Zhernakova, J. W. Dallinga, C. Wijmenga, F. J. Van Schooten, "Factors that influence the volatile organic compound content in human breath", Journal of breath research, Vol-11, pp. 102-112, 2017.

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Santhoshini Arulvallal Mtech Biomedical engineering, Assistant professor, has done publication on topic "sleep apnea detection using smart watch and data analysis using neural network" in a scopus indexed journal, progressing research work in hypertension detection using pulse rate and submitted 3 Research proposals, Once awarded with best paper for the paper "Enhanced security using multimodal meta data Biometric systems".

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