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Comparative Study of the Symptoms of Impending Human Heart, Kidney and Liver Failures Based on Blood Samples

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Abstract: While all the organs of the human body works together for the proper functioning of the entire human system, the significant roles played by the heart, kidney and liver in the lives of humans cannot be overemphasized. The heart, kidney and liver shares one thing in common, namely: the blood from where several parameters that defines the state of human health can be deduced or inferred. This paper is on the comparative study of the possible symptoms of impending human heart, kidney and liver failures based on blood samples that could be used to infer the state of human health with a view for the development of an online real-time electronic health (e-health) monitoring system. The comparative study considered in this work identified 19 vital measurable blood-related parameters that can be classified as follows: *1). Heart:* heart beat, mean arterial blood pressure, systolic blood pressure, diastolic blood pressure; *2). Kidney:* packed cell volume/blood cells, erythropoietin, electrolyte Na^+, electrolyte Cl^-, electrolyte Ca^{2+}, vitamin D; and *3). Liver:* Ceratine, glucose fasting, glucose random, urea, direct bilirubin, total bilirubim (direct and indirect), ammonia level, alpha-feto protein. Detailed discussion on the functions, tests and diagnosis of each of heart, kidney and liver as well as the causes, symptoms, failures, consequences (acute or chronic adverse effects) are also presented. Finally, some preliminary medical advice and suggestions on possible ways to circumvent, reduce and/or manage any impending symptoms of failures of the heart, kidney and/or liver based on the nominal values as well as the minimum and maximum values of the mentioned 19 parameters are given.

Keywords: Blood Samples, Comparative Study, E-health, Heart, Kidney, Liver, Measurable Blood-Related Parameters, Organ Failures

1. Introduction

The importance of making a correct medical diagnosis cannot be over-stressed. There are emotional, legal and financial consequences if an individual is told that he/she is ill when, in fact, he/she is not. The patient suffers extreme emotional distress; the physician may be legally liable for this distress, and, in this time of managed health care, costs for unnecessary medical procedures are incurred. Of far greater consequence, is an improper diagnosis concluding the patient is disease-free when they are not. If proper treatment is withheld due to this misdiagnosis, the patient will suffer and possibly die unnecessarily. Any technology that can improve the ability to correctly diagnose human illness is a needed advance to humanity's wellbeing. With the widespread use of electronic data capture and automation of medical records, medical diagnostic decision support systems (MDDSS) have become a valuable aid in improving the accuracy of medical diagnosis [1–5].

The heart, kidney and/or liver failure is a life-threatening condition that demands early detection as well as urgent medical attention. The failure of all or any of these three organs can be acute (over days or weeks) or chronic (over months or years). The heart, kidney and liver share one thing

in common, namely: the blood from where human state of health can be deduced and/or inferred. For the heart, uncontrolled high blood pressure (hypertension) is a major cause of heart failure even in the absence of a heart attack [6–9]. On the other hand, while kidney ensures the removal of waste and excess fluid from the blood, kidney failure raises the risk of other cardiovascular problems such as blockage of blood to the heart and congestive heart failure [10–16]. Apart from the liver's main job of filtering the blood coming from the digestive track before passing it to the rest of the body; the liver also carry out a large number of critical functions including the manufacture of essential proteins and metabolism of fats and carbohydrates, eliminates harmful biochemical waste products, and secretes bile that contains bile acids which aid in the digestion and intestinal absorption of fats and vitamins [17–22].

Heart failure does not mean that the heart has stopped working. Rather, it means that the heart's pumping power is weaker than normal. With heart failure, blood moves through the heart and body at slower rate and the pressure in the heart increases. As a result the heart cannot pump enough oxygen and nutrients to meet the body's needs [23]. The chambers of the heart may respond by stretching to hold more blood to pump through the body or by becoming stiff and thickened. This helps to keep the body moving, but the heart muscle walls may eventually weaken and become unable to pump efficiently [24]. As a result, the kidney may respond by causing the body to retain fluid (water) and salt. If fluid builds up in the arms, legs, ankle, feet, lungs or other organs the body becomes congested, and congested heart failures is the term used to describe the condition [6–9, 25].

Kidney failure occurs when the kidney is no longer able to remove waste from the body. Kidney failure can happen suddenly or gradually [26]. People with kidney failure need dialysis or a transplant to stay alive. Acute kidney injury (also called acute renal failure) means that the kidney have suddenly stopped working, kidney remove waste products and help balance water and salt and other minerals (electrolyte) in the body [26]. When the kidney stops working, waste products, fluid and electrolyte builds up in the body which can cause problems that could be deadly. The kidneys are two organs located on either side of the spine in the middle at the back just above the waist. They perform several life sustaining roles [26]. They cleanse the blood by removing waste and excess fluids, maintain the balance of salt and mineral in the blood and help regulate blood pressure. When the kidney become damaged, waste products and fluid can build up in the body thereby causing swelling in the body ankles, vomiting, weakness, poor sleep and shortness of breath if left untreated. Diseased kidney may eventually stop functioning completely. Loss of kidney function is a serious and potentially fatal condition [10–16, 25]

The liver is a vital organ of the digested system present in vertebrates and some other animals. It has a wide range of functions, including detoxification, protein synthesis, and production of biochemical necessary for digestion. The liver is necessary for survival. There is currently no way to compensate for the absence of liver function in the long term, although new liver dialysis techniques can be used in the short term [27]. This gland plays a major role in metabolism and has a number of functions in the body, including glycogen storage, decomposition of red blood cells, plasma protein synthesis, hormone production and detoxification. It lies below the diaphragm in the abdominal-pelvic region of the abdomen. It produces bile, an alkaline compound which aids in digestion via the emulsification of lipids [28]. The liver's highly specialized tissues regulate a wide variety of high volume biochemical reactions, including the synthesis and breaking down of small and complex molecules, many of which are necessary for normal vital function [17–22, 29].

The liver is reddish brown organ with four lobes of unequal size and shape. The human liver normally weighs 1.44 to 1.66 kg and is a soft, reddish-brown, triangular organ. It is both the large internal organ (the skin being the largest organ overall) and the largest gland in the human body. It is located in the right upper quadrant of the abdominal cavity, resting just below the diaphragm. The liver lies to the right of the stomach and overlies the gallbladder. It is connected to two large blood vessels, one called the hepatic artery and the other called portal vein. The hepatic artery carries blood from the aorta, whereas the portal vein carries blood containing digested nutrient from the entire gastrointestinal tract and also from the spleen and pancreas. These blood vessels subdivide into capillaries, which then leads to a lobule. Each lobule is made up of millions of hepatic cells which are in basic metabolic cells. The lobules are the functional units of the liver [30].

In this paper, a comparative study of the symptoms of impending heart, kidney and liver failures based on human blood samples acquired from data of patients is investigated with a view to ascertain the parameters that could be used to infer the state of the heart, kidney and liver. The paper is organized as follows. Section 2 presents the causes, symptoms and possible diagnostic tests of heart, kidney and livers failures. Section 3 investigates some measurable blood-related parameters that could be independently or collectively used to determine the state of the heart, kidney and liver. Detailed discussions of the acquired data based on nominal value for normal healthy human beings are also presented in this section. Section 4 concludes the paper with major highlights on the contributions of the paper and some directions on further work.

2. Heart, Kidney and Liver: Causes, Symptoms and Diagnosis

Heart, kidney and liver failures are most of the life-threatening diseases and they have more impact on human health [27, 28, 31, 32]. Several research works have undertaken to provide more attention in their diagnosis [6–22]. Various causes, symptoms and diagnosis of heart, kidney and liver failures is discussed in the next sub-sections.

And the various medical expert systems employed in literatures for proper diagnosis is also presented in the subsequent sections.

2.1. The Heart

2.1.1. Heart Failure

Heart failure does not mean that the heart has stop working rather it means that the heart's pumping power is weaker than normal [25]. With heart failure, blood moves through the heart and body at a slower rate and the pressure in the heart increases. As a result, the heart cannot pump enough oxygen and nutrient to meet the body's needs [33]. The chamber of the heart may respond by stretching to hold more blood to pump through the body or by becoming stiff and thickened. This helps to keep the body moving, but the heart muscle walls may eventually weaken and become unable to pump blood efficiently. As a result, the kidneys may respond by causing the body to retain fluid (water) and salt [33]. If fluid builds up in the arms, legs, ankles, feet, lungs, or other organs the body becomes congested and congestive heart failure in the term used to describe these conditions. Heart failure is a condition in which the heart is no longer able to pump out enough oxygen-rich blood. This causes symptoms to occur throughout the body [6–9, 25].

2.1.2. Causes of Heart Failure

Conditions that damage or overwork the heart muscle can cause heart failure [25]. Overtime the heart weakness. It is not able to fill with and/or pump blood as well as it should. As the heart weakness, certain proteins and substances might be released into the blood. These substances have a toxic effect on the heart and blood flow, and they worsen heart failure. According to [6–9, 31, 33–35], the most common causes of heart failure are coronary heart disease (CHD), high blood pressure, heart attack, cardiomyopathy and diabetes.

1) Coronary Heart Disease (CHD): Coronary heart disease is a condition in which a waxy substance called plaque builds up inside the coronary arteries. These arteries supply oxygen-rich blood to the heart muscle [34, 35]. Plaque narrows the arteries and reduces blood flow to the heart muscle. The build-up of plaque also makes it more likely that blood clots will form in the arteries. Blood clots can partially or completely block blood flow. CHD can lead to chest pain or discomfort called angina, a heart attack, heart damage or even death [34, 35].

2) High Blood Pressure: Blood pressure (BP) is the force of blood pushing against the walls of the arteries [24]. If this pressure rises and stays high over time, it can weaken the heart and lead to plaque build-up. Blood pressure is considered high if it stays at or above 140/90 mmHg overtime [33]. The mmHg is millimetres of mercury - the units used to measure blood pressure. If someone have diabetes or chronic kidney disease, high blood pressure is defined as 130/80 mmHg or high [34, 35].

3) Heart Attack: A heart attack occurs when a coronary artery becomes suddenly blocked, stopping the flow of blood to the heart muscle. A heart attack damages the heart muscle, resulting in a scarred area that do not function properly [34, 35].

4) Cardiomyopathy: Damages to the heart muscle from causes other than artery blood flow problems, such as from infections or alcohol or drug abuse [34, 35].

5) Diabetes: Diabetes is a disease in which the body's blood glucose (sugar) level is too high. The body normally breaks down food into glucose and then carries it to cells throughout the body [36]. The cells use a hormone called insulin to turn the glucose into energy [36]. In diabetes, the body doesn't make enough insulin or doesn't use its insulin properly. Over time, high blood sugar level can damage and weaken the heart muscle and the blood vessels around the heart, leading to heart failure [31, 34, 35].

2.1.3. Symptoms of Impending Heart Failure

Symptoms of heart failure often begin slowly. At first, they may only occur when patient are very active [6–9, 31, 33–35]. Overtime, the patient may notice breathing problems and other symptoms even when he/she is resting. Symptoms may also appear suddenly after the heart is damaged from heart attack or other problems [31, 34, 35].

Common symptoms of Heart failure are [6–9, 25, 31, 33–35]: 1). Shortness of breath (dyspnea) when you exert yourself or when you lie down; 2). Fatigue and weakness; 3). Swelling (edema) in the legs, ankles and feet; 4). Rapid or irregular heartbeat; 5). Reduced ability to exercise; 6). Persistent cough or wheezing with white or pink blood–tinged phlegm; 7). Increased need to urinate at night; 8). Swelling of abdomen (ascites); 9). Sudden weight gain from fluid retention; 10). Lack of appetite and nausea; 11). Sudden, severe shortness of breath and coughing up pink foamy mucus; 12). Elevated blood pressure; and 13). Chest pain, if the heart failure is caused by a heart attack.

All of these symptoms are the result of fluid buildup in the body. When symptoms start, one may feel tired and short of breath after routine physical effort, like climbing stairs. As the heart grows weaker, symptoms get worse. One may begin to feel tired and short of breathe after getting dressed or walking across the room. Some people may have shortness of breath while lying flat. Fluid build-up from heart failure also causes weight gain, frequent urination, and a cough that's worse at night and when lying down. This cough may be a sign of acute pulmonary edema and it is a condition in which too much fluid builds up in the lungs. This condition requires emergency treatment.

2.1.4. Tests and Diagnosis of Heart Failure

To diagnose heart failure, doctor will take a careful medical history and perform a physical examination. The doctor will also check for the presence of risk factors such as high blood pressure. Using a stethoscope, the doctor can listen to the lungs for signs of congestion. The stethoscope also picks up abnormal heart sounds that may suggest heart

failure. The doctor may examine the veins in the neck and check for fluid build-up in the abdomen and legs. After the physical exam the doctor may also order some of these tests [6–9, 25, 31, 33–35]:

1) Blood Tests: The doctor may take a sample of some blood to check for the kidney and thyroid function and to look for indications of other disease that affect the heart. A blood test to check for a chemical called N-terminal pro-B-type natriuretic peptide (NT-pro BNP) can help in diagnosing heart failure.

2) Chest X-ray: X-ray images helps the doctor to see the condition of the lungs and heart. In heart failure, patient's heart may appear enlarged and fluid build-up may be visible in the lungs. The doctor can also use an x-ray to diagnose conditions other heart that may explain the signs and symptoms.

3) Electrocardiogram (ECG): This test records the electrical activity of the heart through electrodes attached to the skin and impulses are recorded as waves displayed on a monitor or printed on paper. This test helps the doctor diagnose heart rhythm problems and damage to the heart from a heart attack that may be underlying heart failure.

4) Myocardial Biopsy: In this test, doctor will inserts a small flexible biopsy cord into a vein in the neck or groin, and small pieces of the heart muscle are taken. This test is performed to diagnose certain types of heart muscle diseases that cause heart failure.

2.2. The Kidney

2.2.1. Kidney and Kidney Disease

The kidneys are two organs located on either side of the spine in the middle at the back, just above the waist. They perform several life sustaining roles: They cleanse the blood by removing waste and excess fluid maintain the balance of salt and minerals in the blood, and help to regulate blood pressure. When the kidneys become damaged, waste products and fluids can build up in the body, causing swelling in the ankles, vomiting, weakness, poor sleep and shortness of breath. If the kidney is left untreated, diseased kidneys may eventually stop functioning completely. Loss of kidneys functions is a serious and potentially fatal condition.

Healthy kidneys handle several specific roles such as [10–16]: *1)*. Maintain a balance of water and concentration of minerals, such as sodium, potassium, and phosphorus in the body; *2)*. Remove waste by–products from the blood after digestion, muscle activity and exposure to chemicals or medications; *3)*. Produce rennin, an enzyme that helps regulate blood pressure; *4)*. Produce erythropoietin, which stimulates red blood cell production; and *5)*. Produce an active form of vitamin D, needed for bone health.

2.2.2. Kidney Failure: What to Expect

For an impending kidney failure, one or more of the following should be expected and/or answered: *1)*. How does kidney failure affect a person's health?; *2)*. When is

uremia likely to occur?; *3)*. Can uremia be avoided?; *4)*. How does kidney failure affect the blood?; *5)*. How does kidney failure affect the heart and blood vessels?; and *6)*. How does kidney failure affect appetite? A brief detail of the above six expectations are briefly discussed as follows [10–16, 25]:

1) How Does Kidney Failure Affect a Person's Health?

Kidney failure can affect a person's health is several way. Some people experience fatigues some lose their appetite, and some have leg cramps [25]. These problems are caused by waste products that build up in the blood, a condition known as uremia. Healthy kidneys remove waste products from the blood. When the kidneys stop working uremia occurs. The kidney also produces hormones and balances the minerals in the blood [25]. When the kidneys stop working, most people develop condition that affect the blood, bones, nerves and skin. In addition to fatigue, loss of appetite, leg cramps, some of the more common problems caused by kidney failure are itching, sleeping problems, restless legs, weak bones, joint problems, and depression.

2) When is Uremia Likely to Occur?

It occurs when a person reaches the final stages of chronic kidney disease (CKD), people with CKD often feel no symptoms until the kidneys are severally damaged. Usually when people develop symptoms, their kidney failure has progressed to the point where they must have regular blood – filtering treatments called dialysis or receive a kidney transplant to stay alive. Kidney failure treated by dialysis or transplant is called end–stage renal disease (ESRD). The word "renal" refers to the kidneys. Even people who have dialysis treatments can eat foods not recommended for people on dialysis [37].

3) Can Uremia be Avoided?

People with kidney failure can avoid most of the problems of uremia by having regular dialysis treatments and limiting foods that contain sodium, potassium and phosphorus. People who have CKD should see a kidney specialist – called nephrologists regularly to track the progression of the disease so they can begin appropriate treatment before uremia occurs. Even though health care providers can treat most of the complications of CKD and ESRD, people with these conditions should know what to expect when their kidneys fails [10–16].

4) How does Kidney Failure Affect the Blood?

In addition to uremia, kidney failure can also cause anemia, a condition in which the red blood cells are fewer or smaller than normal which means less oxygen is carried to the body's cells. Anemia is common in people with CKD, as well as those on dialysis, because the damaged kidneys slow the production of the hormone erythropoietin (EPO), which helps the bone marrow make red blood cells. Less EPO means the body has fewer red blood cells resulting in anemia. Asynthetic form of EPO is commonly prescribed for people on dialysis [10–16].

5) How does kidney Failure Affect the Heart and Blood Vessels?

People with kidney failure, particularly dialysis patients have far higher rates of heart and blood vessels problems than people without kidney problems Heart attacks are the leading cause of hospitalization and death among dialysis patients. Kidney failure also raises the risk of other cardiovascular problems such as blockage of blood to the heart and congestive heart failure. People who have kidney failure need to monitor their cardiovascular health, take all prescribed medications, and follow their health care provider's instructions for diet and exercise [10–16].

6) How does kidney Failure Affect the Appetite?

People who have uremia often lose their appetite, some people find that food tastes different while some no longer like food they once craved for. In fact, many people feel sick to their stomach at the thought of eating. But getting enough protein and calories is important for staying healthy. People with kidney failure should talk with the renal dietitian at their dialysis clinic or transplant center to find foods that are appealing and provide needed nutrients [10–16].

2.2.3. Causes of Kidney Failure

The possible causes of kidney failure include but not limited to the following [10–16, 25]: *1).* Diabetic Nephropathy: Even if it is well managed, diabetes can cause kidney damage; *2).* Hypertension: High blood pressure; *3).* Glomerulonephritism: Swelling or inflammation of the tiny filtering units (nephrons) in the kidney; *4).* Polycystic Kidney Disease: An inherited condition that causes hundreds of crystals to form in the kidneys; and *5).* Reflex Nephropathy: A bladder–value problems that allows urine to flow back into the kidney causing scarring.

2.3. The Liver

The liver is a vital organ of the digestive system present in vertebrates and some other animals. It has a wide range of functions including detoxification, protein synthesis, and production of biochemical necessary for digestion [17–22, 33]. The liver is necessary for survival because there is currently no way to compensate for the absence of liver function in the lung term, although new liver dialysis techniques can be used in the short term. This gland plays a major role in metabolism and has a number of functions in the body, including glycogen storage, decomposition of red blood cells, plasma protein synthesis, hormone production, and detoxification [24]. It lies below the diaphragm in the abdominal – pelvic region of the abdomen. It produces bile, an alkaline compound which aids in digestion via the emulsification of lipids. The liver's highly specialized tissues regulate a wide variety of high–volume biochemical reactions, including the synthesis and breakdown of small and complex molecules, many of which are necessary for normal vital functions [38].

The big question is "What are the basic functions of the liver?". The liver is located in the right upper portion of the abdominal cavity just beneath the right side of the rib cage. The liver has many functions that are vital to life. Some of the important functions of the human liver are: *1).* Detoxification of blood; *2).* Production of important clotting factors, albumin, and many other important proteins; *3).* Metabolizing (processing) medications and nutrients; *4).* Processing of waste products of haemoglobin and other cells; and *5).* Storing of vitamins, fat, cholesterol, and bile.

Liver Failure

Liver failure occurs when large parts of the liver become damaged beyond repair and the liver is no longer able to function. Liver failure is a life–threatening condition that demands urgent medical care. Most often, liver failure occur gradually and over many years. However, a more rare condition known as acute liver failure occur rapidly (as little as 48 hours) and can be difficult to detect initially [25, 33].

Although the list of possible causes of live failure could be exhaustive and liver failure could be as a result of severe deterioration in liver function which could be attributed to one and/or more of the following [17–23, 25, 33]: *1).* Liver failure is caused by a disorder or substance that damages the liver; *2).* Most people have jaundice, feel tired and weak, and lose their appetite; *3).* Other symptoms include accumulation of fluid within the abdomen (ascites) and a tendency to bruise and bleed easily; *4).* Doctors can usually diagnose liver failure based on symptoms and results of a physical examination and blood tests; and *5).* Treatment usually involves controlling protein consumption, limiting sodium in the diet, completely avoiding alcohol, and treating the cause, but sometimes liver transplantation is required. Liver failure can result from any type of disorder, including viral hepatitis, cirrhosis, and liver damage from alcohol or drugs such as acetaminophen.

Many effects that could occur due to the malfunctioning of the liver may include but not limited to the following: *1).* The liver can no longer adequately process bilirubin (a waste product formed when old red blood cells are broken down) so that it can be eliminated from the body. Bilirubin then builds up in the blood and is deposited in the skin. The result is jaundice; *2).* Liver can no longer synthesize enough of the proteins that help blood clot. The result is a tendency to bruise and bleed (coagulopathy); *3).* Blood pressure in the veins that bring blood from the intestine to the liver is often abnormally high (called portal hypertension); *4).* Fluid may accumulate within the abdomen (ascites); and *5).* Brain function may deteriorate because the liver cannot remove toxic substances as it normally does. These substances build-up in the blood and causes brain functions to deteriorate. This disorder is called hepatic encephalopathy.

Table 1. *Measurable blood-related heart, kidney and liver parameters.*

	Heart Parameters	Kidney Parameters	Liver Parameters
1	Pulse rate and rhythm	Packed cell volume/blood cells	Bilirubin and bile salt levels
2	Arterial blood gas such as oxygen (O_2) and carbon IV oxide (CO_2)	Electrolytes (Na^+, K^+, Cl^+, creatinine, urea, uric acid, Ca^{2+}, PO_4^-)	Protein
3	Arterial pressure and blood pressure	Erythropoietin	Clotting factors (II, V, X) in terms of prothrombin time (PT) and international normalized ratio (INR)
		Vitamin D level	NH_4 or urea, α-feto (alpha-feto) protein, Glucose level

Table 2. *Minimum and maximum values of the all the parameters considered for the study.*

S/N	Measured blood parameters and their units	Minimum value	Maximum value
1.	Heart beats (*number of heat beats per minute*)	65	105
2.	Mean arterial pressure (*mmHg*)	65	115
3.	Systolic blood pressure (*mmHg*)	85	150
4.	Diastolic blood pressure (*mmHg*)	60	110
5.	Packed cell volume (*%*)	33	53
6.	Erythropoietin (*mu/ml*)	4	26
7.	Electrolyte Na^+ (*mol/l*)	118	143
8.	Electrolyte K^+ (*mol/l*)	3	5
9.	Electrolyte Cl^- (*mol/l*)	92	113
10.	Electrolyte Ca^+ (*mol/l*)	2	3
11.	Ceratine (*Umol/l*)	48	133
12.	Glucose fasting (*mol/l*)	2	6
13.	Glucose random (*mol/l*)	4	7
14.	Urea (*mmol/l*)	60	110
15.	Direct bilirubin (*mg/dl*)	0.0027	0.4973
16.	Total bilirubin (direct and indirect) (*mg/dl*)	0.1000	2.2000
17.	Vitamin D level (*mg/ml*)	0	40
18.	Ammonia level (*mcg/dl*)	9	80
19.	Alpha-feto protein (*ng/ml*)	7	500

3. Problem Formulation, Materials and Methods

3.1. Problem Formulation: Measurable Blood-Related Heart, Kidney and Liver Parameters

The focus here is to investigate how the symptoms of impending heart, kidney and liver failures could be detected in a given blood sample. Interactions with medical experts and ideas from reviewed literature revealed that some key factors which should be observed in order to suspect, detect or ascertain the symptoms of impending heart, kidney and liver failures based on blood sample from human beings are summarized in Table 1.

1) The Heart:
   (1) The pulse is how many times per minute that the artery expands and contracts in response to the heart pulse rate which is also called heartbeat. Normal adult resting heartbeat is between 60 – 100 heartbeats per minute;
   (2) Mean arterial pressure is between 60 mmHg or greater is needed to maintain adequate tissue per fusion; and
   (3) The blood pressure consist of the systolic which must be less than or equal to 140 mmHg while the diastolic must be less than or equal to 90 mmHg.
2) The Kidney:
   (1) Packed cell volume / blood cell: (a) Male should be between 40 – 50% and (b) Female should be between 35 – 44%;
   (2) Erythropoetin should be between (4 – 24 mu/ml); and
   (3) Electrolytes: (a) Na^+ should be between (120 – 140 mol/l); (b) K^+ should be between (3 – 5 mol/l); (c) Cl^+ should be between (95 – 110 mol/l); (d) Ca^+ should be between (2.25 – 2.75 mol/l); (e) Creatinine (male and female) should be between (50 – 130 Umol/l); (f) Urea should be between (2.0 – 6.0 mmol/l); (g) Glucose fasting should be between 3.0 – 5.5 mol/l; and (h) Glucose random should be between 4.4 – 7.0 mol/l
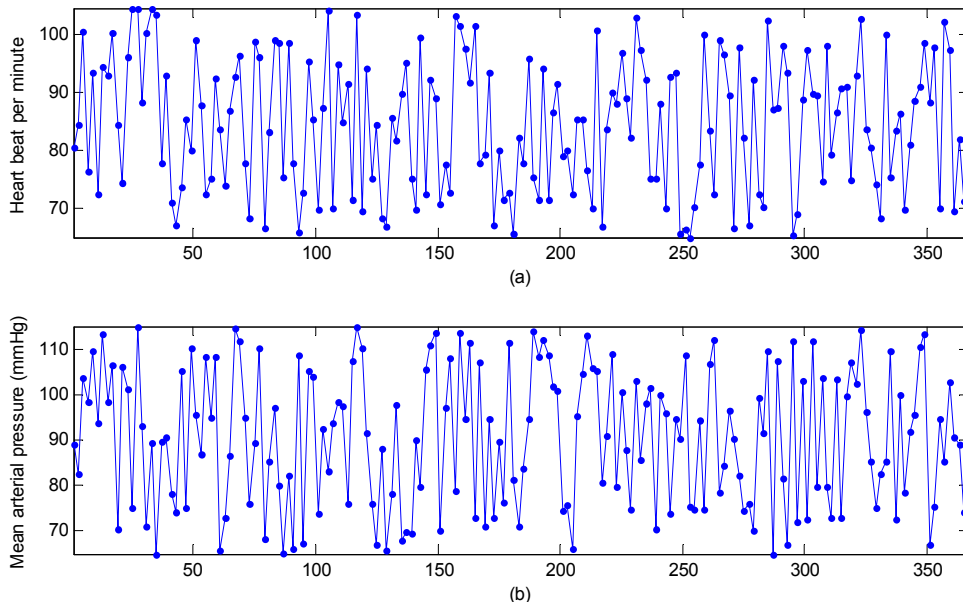
Figure 1. *Variations of (a) heart beat per minute and (b) arterial blood pressure.*
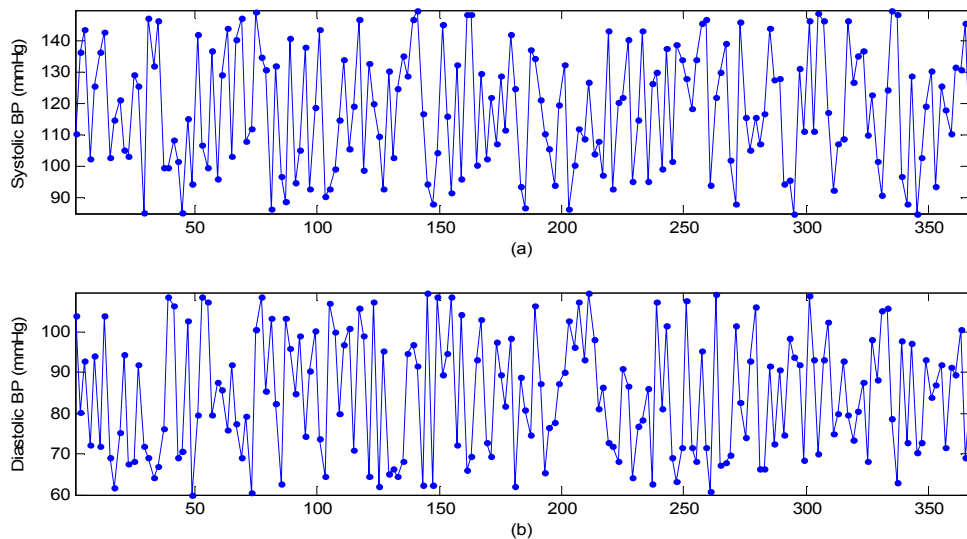
Figure 2. *Blood pressure: (a) Systtolic blood pressure (mmHg) and (b) Diastolic blood pressure (mmHg).*

3) The Liver:
(1) Bilirubin: Normal values of direct (conjugated) bilirubin are from 0.0 – 0.3 mg/dl. Normal values of total bilirubin (direct and indirect) are from 0.3 – 1.9 mg/dl;
(2) Vitamin D Level: The normal range of vitamin D is wide but typically between 20 – 40 mg/ml and in some cases between 50 – 100 mg/ml; and
(3) Ammonia Level: (a) Adult is between 9.5 – 49 mcg/dl; (b) Children is between 40 – 80 mcg/dl and (iv) alpha-feto protein: Normal levels are below 10 ng/ml.

3.2. Discussion of the Heart, Kidney and Liver Experimental Data

A total of 368 data each for 16 out of the 19 measurable blood-related parameters listed in the previous Sub-section were collected from different hospitals in Akure, Ondo State, Nigeria. For confidential and security reasons, the bio-data and information for the patients from the where the data were collected have been skipped in this paper. From our comparative study, the 16 attributes of interest that could be acquired from the hospitals contacted which could be used to detect heart, kidney and liver failure for: *(1)* Heart beat per minutes, *(2)* mean arterial pressure (mmHg), *(3)* systolic Bp (mmHg), *(4)* diastolic Bp, *(5)* potassium, *(6)* chlorine, *(7)* calcium, *(8)* creatine (umol/l), *(9)* glucose fasting (mol/l), *(10)* glucose random (mol/l), *(11)* urea (mmol/l), *(12)* direct bilirubin (mg/dl), (13) total bilirubin (mg/dl), (14) Vitamin D (ng/ml), *(15)* ammonia (mcg/dl), and *(16)* alpha-feto (ng/ml). Figure 1 to Figure 6 shows the variations of these attributes from the test data collected for 368 patients which are discussed as follows. Furthermore, the minimum and

maximum values of the 19 measureable blood-related parameters are listed in Table 2.

Figure 1(a) and (b) shows the variations of heart beat per minute and arterial pressure from the 368 patients respectively. The normal heart beat of a human being is between 60-100 or 65-105 per minute, normal arterial pressure (blood pressure) ranges from 100/60–140/80 mmHg if the patient arterial pressure (blood pressure) is around 150/100 mmHg the lifestyle changes and the use of medicine can improve the condition of the patient. Any patient with arterial pressure (blood pressure) of 180/80 mmHg upward is not a normal patient [6–9, 25], such patient should be monitored by a doctor and he/she will have to follow up appointment at least every 3 to 6 months, but sometimes much more often. The doctor will also have to carry out tests to check the heart functions. Additionally, the doctor will also need to know the state of the patient and the symptoms that will inform the doctor whether or not the heart failure is getting worse; which will guide the doctor to help the patient stay healthier even when he/she is out of the hospital. While out of hospital, the patient should be monitored for changes in the heart rate, heart pulse, blood pressure and weight. Also patients with blood pressures of 190/100 mmHg upward are amongst the leading cause of sudden deaths globally [6–9, 25]. In order to control the risks associated with the disease, it is crucial to monitor weight gain, especially over a day or two. This can be a sign that the body is holding onto extra fluid and the heart failure is getting worse. For middle-aged and older-aged, high blood pressure is an important indicator for cardiovascular diseases, which are amongst the leading cause of sudden deaths [6–9, 25].

Figure 2(a) and (b), shows the systolic blood pressure (in mmHg) and diastolic blood pressure (in mmHg) respectively. Systolic heart failure is when the heart muscles cannot pump (eject) blood out of the heart very well while diastolic heart failure is when the heart muscles are stiff and do not fill up with blood easily which makes it a vital attributes of the blood as a parameter that could be used to infer the state of health of an individual [2]. Normal systolic blood pressure ranges from 85 to 150 mmHg. If the patient experiences more than 90/160 mmHg such patient lifestyle changes and the use of medicine can improve the condition of the patient [25]. On the other hand, if it is not up 80 mmHg at a certain point the health care provider will decide whether it is best to keep treating aggressively the patient along with his/her family and doctor may want to discuss palliative or comfort care at this time. Diastolic blood pressure ranges from 60 to 110 mmHg. If the patient experiences blood pressure above 80/120 mmHg the patient lifestyle changes and if it is below 60 mmHg the use of medicine can improve the condition of the patient [25]. It is important that the patient take his/her medicine as prescribed and directed by the doctor directed, they should not take any drugs or herbs without first asking the doctor or nurse about them, because there are some drugs that can make heart failure worse. Such drugs include Ibuprofen and Naproxen. The only prevention is by living a healthy lifestyle and reducing the risk for heart disease [2, 4, 6–9, 25].

Figure 3(a), (b) and (c) shows, potassium (k^+) (in mol/l), chlorine (Cl^+) (in mol/l) and calcium (Ca^+) (in mol/l) respectively. Normal electrolyte potassium (mol/l) ranges from 3 to 5 mol/l. If the patient electrolyte potassium is around 5 upward or below 3 mol/l, the lifestyle changes and the use of medicine can improve the condition of the patient [10–16, 25]. Normal electrolyte chlorine (mol/l) ranges from 95 to 110 mol/l or 92 to 113 mol/l. If the patient electrolyte chlorine (in mol/l) is around 90/120, the lifestyle changes and if the patient is below 90 mol/l the use of medicine can improve the condition of the patient. Any patient with 100/130 mol/l or above is not a normal patient and are amongst the leading cause of sudden deaths. Normal electrolyte calcium (mol/l) ranges from 2.25 to 2.75 mol/l or 2.22 to 2.78 mol/l [25]. If the patient electrolyte calcium is around 2.35 to 2.85, the patient's lifestyle will change. Maintaining a balance of water and concentration of minerals such as potassium, chlorine and calcium in the blood, remove waste by-products from the blood after digestion, controls muscle activities, and combats exposure to chemicals or excess and/or misuse of medications, it helps filter waste excess fluid and toxins from the blood. They are also important for blood cell production and bone health. If the kidney does not work properly [25], harmful substances build up in the body, blood pressure can rise and too much fluid can collect in the body's tissues, which leads to swelling electrolyte levels in the blood and may be abnormally high or low because of improper filtering. The only prevention is by controlling blood pressure which will slow further kidney damage, Angiotensin converting enzyme (ACE) inhibitors or angiotensin receptor blockers (ARBs) are used most often with a goal to keep blood pressure at or below 130/80 mmHg [10–16, 25].

Figure 4(a), (b) and (c) show the distribution of creatinine (in Umol/l), glucose fasting (in mol/l) and glucose random (in mol/l) respectively for the present study. Creatinine (Umol/l) is a waste product that comes from the normal wear and tear on muscles of the body. Creatinine levels in the blood can vary depending on age, race and body size. It is a chemical waste molecules that is generated from muscles metabolism [10–16, 25]. Normal creatinine for both male and female ranges between 50 and 130 Umol/l [10–16, 25]. The lower range is 50 while the higher range is 130 Umol/l in normal human beings. If it is greater or less than this range the lifestyle of the individual changes and the use of medicine can improve the condition of the patient [25]. In order to control the risk associated with the diseases, it is crucial to monitor the creatinine level of the patient frequently. The normal range for glucose fasting is between 3.0 and 5.5 mol/l while the normal range for glucose random ranges from 4 to 7 mol/l, most people do not have any kidney problem from taking medicines. But people who have serious, long-time health problem are more likely than other people who have a kidney problem from medicine [25]. For example, medicines that can sometimes harm the kidney include; antibiotics such as gentamicin and streptomycin. For people who are on dialysis or approaching total kidney failure,

adequate nutrition is important for maintaining energy, strength, healthy sleep pattern, bone health, heart health and good mental health. An individual's state of health will dictate the type of treatment that should be administered.
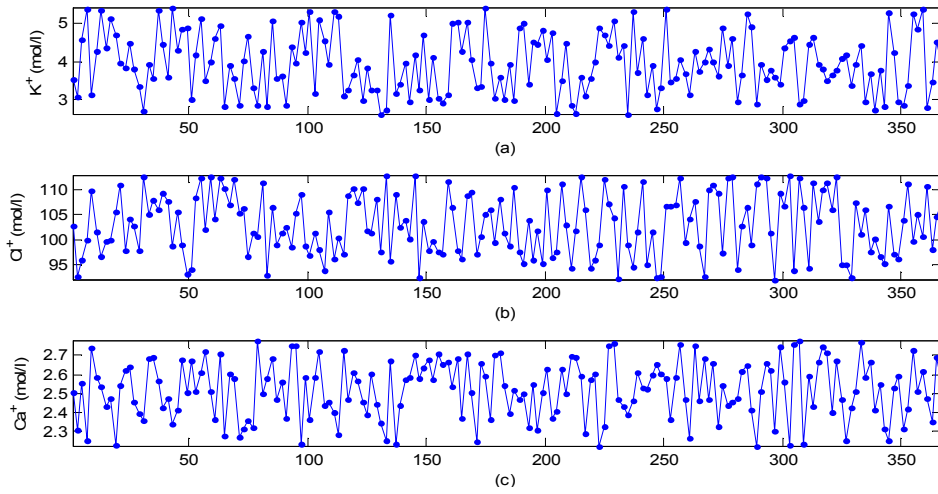
Figure 3. *(a) Potassium (k^+) (mol/l), (b) chlorine (cl^+) (mol/l) and (c) calcium (ca^+) (mol/l).*
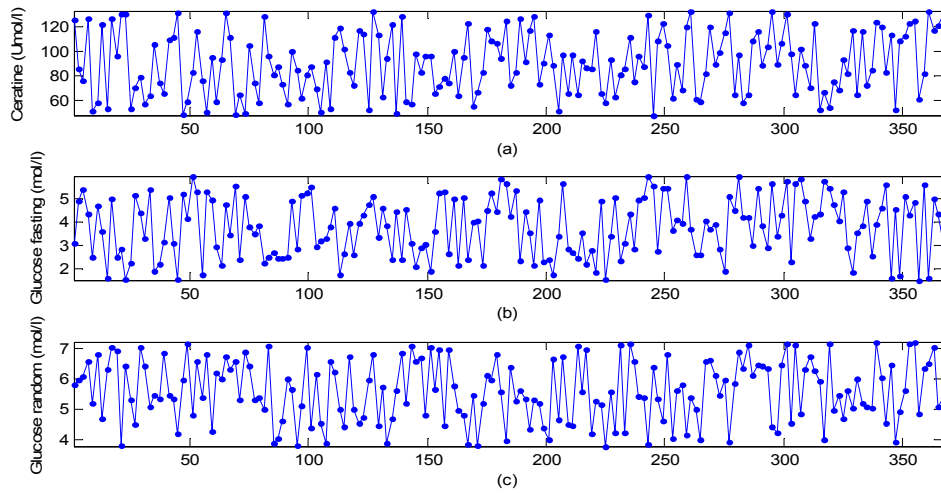
Figure 4. *(a) Creatinine (Umol/l), (b) glucose fasting (mol/l) and (c) glucose random.*
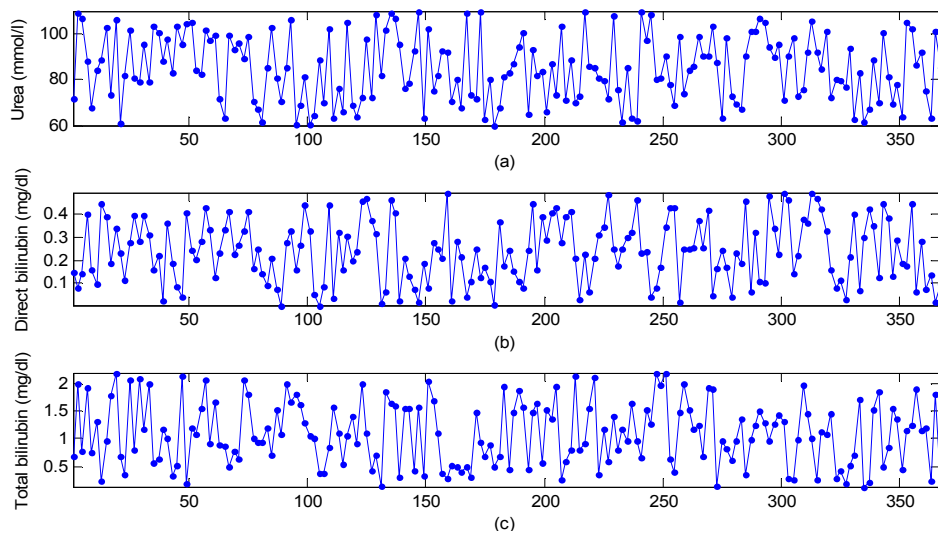
Figure 5. *(a) urea (mmol/l), (b) total bilirubin direct and (c) bilirubin direct.*
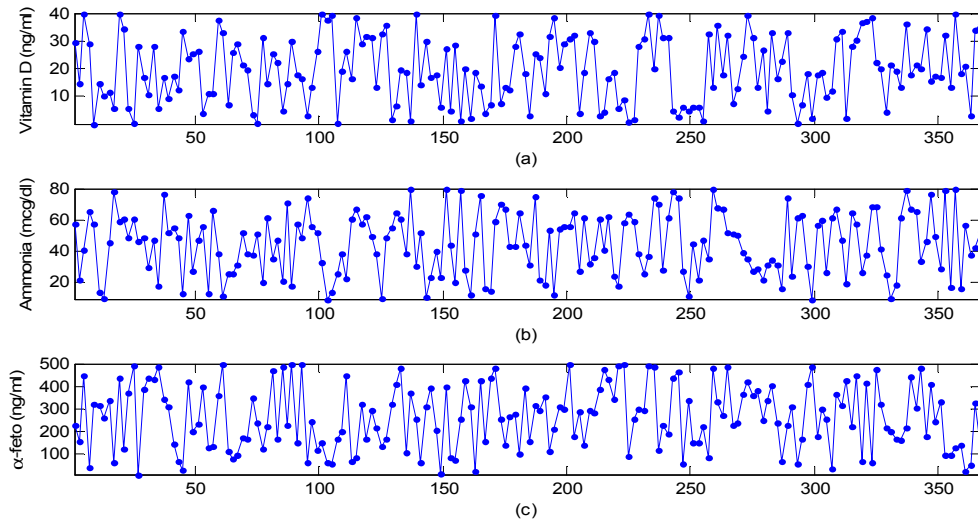
***Figure 6.** (a) vitamin D level, (b) ammonia and (c) alpha-feto protein.*

To determine whether someone has this disease, he or she may need tests and procedures such as blood test to look for the level of waste products such as creatinine and urea in the blood [10–16, 25].

Figure 5(a), (b) and (c) shows, urea (in mmol/l), direct bilirubin (in mg/dl) and total bilirubin (direct and indirect with units in mg/dl) respectively. Urea in normal humans ranges from 60 mol/l to 110 mol/l as shown in Figure 5(a). If it is less than or not equal to these normal ranges, it implies that the patient lifestyle changes and the use of medicine can improve the health condition of the patient. Any patient with urea of 70/120 (mmol/l) upward is not a normal patient or patient with 80/140 upward is among the leading cause of sudden deaths [17–22, 25]. In order to control the risks associated with the diseases, it is crucial to monitor the urea of the patient frequently. The normal values of direct (conjugated) bilirubin are from 0 to 0.3 mg/dl while normal values of total bilirubin (direct and indirect) are from 0.3 to 1.9 mg/dl [25]. Urinary bilirubin is normally absent but is conjugated when present (dark urine). Normal or raised urinary bilirubin with elevated urobilinogen suggests hepatocellular failure or increased red cell breakdown (e.g. haemolytic jaundice). If clinically jaundiced but serum bilirubin normal and negative urinary bilirubin, then the cause is hypervitaminosis A or high serum carotene from carrots, pumpkins, etc. A treatment depends on the cause and the specific symptoms. The urgency of treatment depends on whether liver failure is acute or chronic, but the principles of treatment are the same. The patient is usually placed on a restricted diet to limit the amount of animal protein, particularly in red meat but also in fish, cheese and eggs. To make sure people get enough protein, doctors advise them to eat more food that contains vegetables, protein (such as soya). The patient should also limit their consumption of sodium (in salt and many foods). Doing so can help prevent fluid from accumulating within the abdomen. Alcohol should be completely avoided because it can worsen liver damage [17–22, 25, 30].

Figure 6(a), (b) and (c) shows vitamin D level, ammonia

and alpha-feto variations respectively from the data collected. The normal vitamin D level is between 20 and 40 ng/ml. If the patient's vitamin D level is around 25 to 45 the lifestyle changes and the use of medicine can improve the condition of the patient. Any patient with vitamin D level 30 to 70 upward is not a normal patient. Vitamin D level of more than 70 ng/ml is amongst the leading causes of sudden deaths. In order to control the risks associated with the disease it is crucial to monitor the vitamin D level of the patient frequently. For middle-aged and older aged, vitamin D is very important for the body and it must not be low or high. Normal ammonia in the body is between 90 or 80 mcg/dl while alpha-feto protein mg/ml ranging from 7 to 500 ng/ml. Moderate level of alpha-feto protein of up to 500 ng/ml can be seen in patients respectively. While the use of medicine can improve the condition(s) of a patient with impending liver failure, in order to control the risk associated with the disease, it is crucial to monitor the ammonia and alpha-feto protein of the patient frequently [17–22, 25, 30].

4. Conclusion and Future Directions

The paper has presented a comparative study of the symptoms of impending human heart, kidney and liver failures based on blood samples. The study identified 25 measurable blood-related parameters for heart, kidney and liver out of which 368 experimental data for 19 of the parameters were obtained from 4 different specialist hospitals in Akure, Ondo State, Nigeria whereas 6 of the parameters were not available from any of the consulted hospitals for most patients. The 19 measurable blood-related parameters with experimental data are (see Table 2): *1). Heart:* heart beat, mean arterial blood pressure, systolic blood pressure, diastolic blood pressure; *2). Kidney:* packed cell volume/blood cells, erythropoietin, electrolyte Na^+, electrolyte Cl^-, electrolyte Ca^{2+}, vitamin D; and *3). Liver:* Ceratine, glucose fating, glucose random, urea, direct bilirubin, total bilirubin (direct and indirect), ammonia level, alpha-feto protein. The 6 measurable blood-related

parameters without experimental data are (see and compare Table 1 and Table 2): *1). Heart:* arterial blood gases such as *(i)* Oxygen (O_2) and *(ii)* Carbon IV oxide (CO_2); *2). Kidney: (i)* Electrolyte (PO_4^-); and *3). Liver: (i)* Clotting factors (II, V, X) in terms of prothrombin, *(ii)* international normalized ratio (INR), *(iii)* bile salt levels.

Critical examination of the heart, kidney and liver under the following topics, namely: *(i)* functions, *(ii)* causes of their failures, *(iii)* symptoms of impending failures, *(iv)* tests and diagnosis, and *(v)* preliminary medical advice and suggestions on possible ways to manage any symptom(s) or any impending failures have been detailed and presented in this study. It should be noted that this study does not, in any way, cover treatment issues on any of the organ(s) failures but rather attempts to identify the possible measurable blood-related parameters that could be used to deduce and infer the state of human health. Extensive discussions of and deductions from the experimental data with their respective minimum and maximum values together with their respective nominal values as far as Ondo State, Nigeria is concerned has been well presented for health monitoring when these respective values are out of range.

Medical expert system is a challenging field, requiring the synergy of different scientific areas. The representation of medical knowledge and expertise, the decision making in the presence of uncertainty and imprecision, and the choice and adaptation of a suitable model are some issues that a medical expert system should take into consideration [39, 40]. Uncertainty is traditionally treated in a probabilistic manner; recently, however, methods based on neuro-fuzzy logic have gained special attention. In the medicine area, many expert systems were designed for the diagnosis and treatment of diseases. Fuzzy expert system has found applications in many areas, among these medical engineering has evolved as one of the key application area of computational intelligence [41, 42]. In the last decade, specifically between 2003 and 2012, a major application area of fuzzy expert system includes diagnosis like local anaesthesia, appendicitis, brain tumor, breast cancer, cardiovascular disease, clinical diagnosis, diabetes, electrocardiogram (ECG) signal evaluation, hypertension diagnosis, liver disorder, lung disease, ovarian cancer, prostate cancer, pulmonary infection, urinary tract infection, prenatal disease detection etc [41–45].

Finally, the development of an adaptive classification algorithm that could be used to classify the state of human health on the basis of the experimental data obtained and used in this study could be considered as a future study with a view on the development of an online real-time electronic health (e-health) monitoring system design and deployment.

Acknowledgement

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