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Sudan University of Sciences and Technology

College of Post Graduate Studies

Prediction of Kidney Failure Using Artificial Neural Networks

تشخيص الفشل الكلوي باستخدام الشبكات العصبية الصناعية

A Thesis Submitted in Partial Fulfillment of The Requirements of the degree awards of MSc. In Biomedical Engineering

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الآيـــــــــــــــة

بـسم الله الـرحمـن الـرحـيـم

(إِنَّا عَرَضْنَا الْأَمَانَةَ عَلَى السَّمَاوَاتِ وَالْأَرْضِ وَالْجِبَالِ فَأَبَيْنَ أَن يَحْمِلْنَهَا وَأَشْفَقْنَ مِنْهَا وَحَمَلَهَا الْإِنسَانُ إِنَّهُ كَانَ ظَلُومًا جَهُولًا)

الاحزاب :(72)

Dedication

To my parents

my brothers

my Sisters

MY FREINDS

To every one struggle to Support me ...

Acknowledgment

Praise to Allah, the Almighty Who supported me and gave me Strength to complete this Work.

I would like to express my gratefulness to my Supervisor Dr. Eltahir Mohamed Hessein for his great efforts and support.

Precious thanks to all staff who works in hemodialysis centers specially Sudanese Germany center.

To everyone helped me specialy (eng: Walla, eng: Mohamed Omer, Rania Khiri and Abd Alhamid Mohamed)

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Abbreviations

ECF: Extra Cellular Fluid

ESRD: End Stage Renal Disease

ANN: Artificial Neural Network

PNN: Probabilistic Neural Network

ASNN: Associative Neural Network

CKD: Chronic Kidney Disease

GFR: Glomerular Filtration Rate

BUN: Blood Urea Nitrogen

Cr: Creatinine

R: Regression

FFBP: Feed Forward Back Propagation

CFBP: Cascade Forward Back Propagation

Abstract

This research intents *to assess the application of artificial neural network in predicting the kidney failure disease*. Kidney failure disease is being observed as a serious challenge to the field of medical with its impact on a mass population of the world. This work explored and analyzed the data generated from 60 kidney patients in many hospitals and hemodialysis centers using data mining technique .

This is done by using Artificial Neural Network technique to select the weight, and connectivity structure to determine system for input variables learning. This work provides Physicians with an instrument assess the dialysis service performance

The study for prediction of kidney failure has been carried out using Feed forward back propagation and Cascade forward back propagation algorithms.

The results of this study demonstrate that an ANN model with variables consisting of (urea, creatinine, potassium, sodium, calcium, phosphorus and uric acid) is classified a total of 60 patients correctly to normal and abnormal.

The best network model produced prediction accuracy of 98.3 percent is given by Feed Forward Back Propagation network (FFBP) .

المستخلص

النوايا من هذا البحث تقييم تطبيق الشبكة العصبية الصناعية في توقع مرض الفشل الكلوي.
يعتبر مرض الفشل الكلوي تحدياً كبيراً في المجال الطبي لتأثيره على أعداد كبيرة من السكان هذه الدراسة قامت بتحليل البيانات التي أخذت من مرضى الفشل الكلوي في العديد من المستشفيات ومراكز غسيل الكلى بإستخدام تقنية التنقيب عن البيانات .
تم ذلك بإستخدام تقنية الشبكات العصبية لإختيار متغيرات المدخلات والأوزان وذلك لتحديد متغيرات دخل نظام التعلم .هذا العمل يساعد الاطباء في تقييم خدمة غسيل الكلى.
تم تنفيذ عملية التنبؤ بمرض الفشل الكلوي بإستخدام شبكة عصبية أمامية التغذية خلفية النقل وشبكة الربط الثلاثي.
نتائج هذه الدراسة أثبتت أن نموذج الشبكة العصبية مع المتغيرات (اليوريا-الكرياتنين- البوتاسيوم- الصوديوم- الكاسيوم- الفسفور- حمض اليوريك) صنفت 60 من المرضى بشكل صحيح.
الدراسةاوضحت ان افضل نموذج شبكة للتنبؤ دقته (98.3) وذلك بإستخدام شبكة عصبية أمامية التغذية خلفية النقل.

Chapter One

Introduction

1-1 General view

Dialysis care is particularly complex and multiple factors may influence patient survival. The cost of such treatment for end stage kidney disease is high and needs attention for reducing it. Individual patient survival may depend on an intricate interrelationship between various demographic and clinical variables, medications, medical interventions and the dialysis treatment prescription [1] .The primary role of the kidneys is to remove metabolic waste products and to maintain water and electrolyte balance. These waste products such as urea and creatinine are derived from the normal breakdown of foods and tissues [2]. The kidneys also maintain stability of the extra –cellular fluid (ECF) volume and electrolyte homeostasis by adjusting excretion of water and electrolytes to balance changes in intake. Chronic renal failure occurs when the kidneys are operating at less than 50% of normal capacity [3]. End-stage renal disease (ESRD) occurs when the kidneys are working at less than 10%-15% of normal capacity [4]. At this stage either transplantation or repetitive kidney dialysis becomes necessary for survival. Much of this excess mortality can be explained by the associated health conditions such as diabetes that lead to kidney failure. Understanding factors that are predictive for the survival of a given patient may allow for targeted interventions for high-risk patients and may suggest improvements areas [3].

1.2 Research Problem

Many people suffer from end stage kidney disease and require some form of renal replacement therapy (either dialysis or kidney transplantation) to sustain life.

1.3 Objectives

The objectives of this work are to:

1. Provide Physicians with an instrument that can automatically assess the dialysis service performance and support better understanding of the evaluation results.

2. Predict the existence of renal failure in any sufferer.

1.4 Methodology

The total of 60 patients have undergone test for renal failure.
Each patient will test and the following values will record:
(Urea, creatinine, potassium, sodium, calcium, phosphorus, uric acid) .
These variables will be the input of artificial neural network. An exploratory three-layer ANN model with a feed forward back propagation algorithm and Cascade forward back propagation model will construct Kidney failure will predict from the output of artificial neural network.

1.5 Thesis layout

This research consists of five chapters. Chapter one is an introduction. Theoretical fundamental are presented in chapter two. The proposed model (methodology) is described in chapter three .Results and discussions are shown in chapter four. Finally chapter five is conclusions and recommendations.

Chapter Two
Theoretical fundamental

2.1 Artificial Neural Network

2.1.1 Introduction

Ever since eternity, one thing that has made human beings stand apart from the rest of the animal kingdom is, its brain .The most intelligent device on earth, the “Human brain” is the driving force that has given us the ever-progressive species diving into technology and development as each day progresses.

Due to his inquisitive nature, man tried to make machines that could do intelligent job processing, and take decisions according to instructions fed to it. What resulted was the machine that revolutionized the whole world, the “Computer” (more technically speaking the Von Neumann Computer). Even though it could perform millions of calculations every second, display incredible graphics and 3-dimentional animations, play audio and video but it made the same mistake every time.

Practice could not make it perfect. So the quest for making more intelligent device continued. These researches lead to birth of more powerful processors with high-tech equipments attached to it, super computers with capabilities to handle more than one task at a time and finally networks with resources sharing facilities. But still the problem of designing machines with intelligent self-learning, loomed large in front of mankind. Then the idea of initiating human brain stuck the designers who started their researches one of the technologies that will change the way computer work Artificial Neural Networks. [5]

In general, Neural Networks are simply mathematical techniques designed to accomplish a variety of tasks. Neural Networks uses a set of

processing elements (or nodes) loosely analogues to neurons in the brain (hence the same, neural networks). These nodes are interconnected in a network that can then identify patterns in data as it is exposed to the data. In a sense, the network learns from the experience just as people do. Neural networks can be configured in various arrangements to perform a range of tasks including pattern recognition, data mining, classification, and process modeling. [6]

2.1.2 Neurons

The conceptual constructs of a neural network stemmed from our early understanding of the human brain. The brain is comprised of billion and billions of interconnected neurons. The fundamental building blocks of this massively parallel cellular structure are really quite simply when studied in isolation. A neuron receives incoming electrochemical signals from its dendrites and collects these signals at the neuron nucleus. The neuron nucleus has a internal threshold that determines if neuron itself tires in response to the incoming information. If the combined incoming signals exceeds this threshold then neuron fires and an electrochemical signal is sent to all neurons connected to the firing neuron on its output connections or axons. Otherwise the incoming signals are ignored and the neuron remains dormant.

There are many types of neurons or cells. From a neuron body (soma) many fine branching fibers, called dendrites, protrude. The dendrites conduct signals to the soma or cell body. Extending from a neuron's soma, at a point called axon hillock (initial segment), is a long giber called an axon, which generally splits into the smaller branches of axonal arborization. The tips of these axon branches impinge either upon the dendrites, somas or axons other neurons or upon effectors. [7]

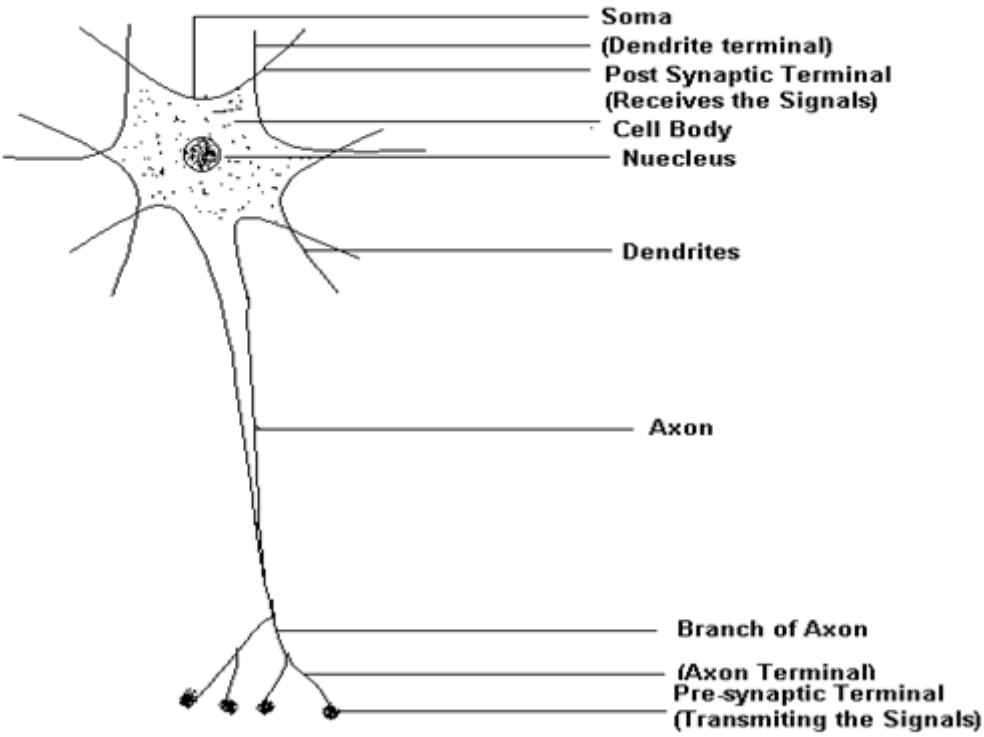

Figure (2.1): A Biological Neuron [7]

2.1.3 Basics of Artificial Neural Models

The human brain is made up of computing elements, called neurons, coupled with sensory receptors (affecters) and effectors. The average human brain, roughly three pounds in weight and 90 cubic inches in volume, is estimated to contain about 100 billion cells of various types. A neuron is a special cell that conducts and electrical signal, and there are about 10 billion neurons in the human brain. The remaining 90 billion cells are called glial or glue cells, and these serve as support cells for the neurons. Each neuron is about one-hundredth size of the period at the end of this sentence. Neurons interact through contacts called synapses. Each synapse spans a gap about a millionth of an inch wide. On the average each neuron receives signals via thousands of synapses.

The motivation for artificial neural network (ANN) researches is the belief that a human's capabilities, particularly in real-time visual perception, speech understanding, and sensory information processing and in adaptively as well as intelligent decision making in general, come from the organizational and computational principles exhibited in the highly complex neural network of the human brain. Expectations of faster and better solution provide us with the challenge to build machines using the same computational and organizational principles, simplified and abstracted from neurobiological of the brain. [8]

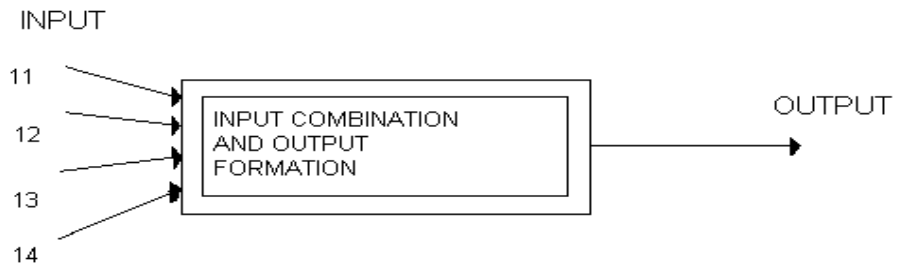

Figure (2.2): Artificial Neural Network Model [8]

2.1.4 Artificial Neural Network

Artificial neural network (ANNs), also called parallel distributed processing systems (PDPs) and connectionist systems, are intended for modeling the organization principles of the central neurons system, with the hope that the biologically inspired computing capabilities of the ANN will allow the cognitive and logically inspired computing capabilities of the ANN will allow the cognitive and sensory tasks to be performed more easily and more satisfactory than with conventional serial processors. Because of the limitation of serial computers, much effort has devoted to the development of the parallel processing architecture; the function of single processor is at a level comparable to that of a neuron.

ANN structures, broadly classified as recurrent (involving feedback) or non-recurrent (without feedback), have numerous processing elements (also dubbed neurons, neurodes, units or cells) and connections (forward and backward interlayer connections between neurons in different layers, forward and backward interlayer connections or lateral connections between neurons in the same layer, and self-connections between the input and output layer of the same neuron. Neural networks may not have differing structures or topology but are also distinguished from one another by the way they learn, the manner in which computations are performed (rule-based, fuzzy, even nonalorithmic), and the component characteristic of the neurons or the input/output description of the synaptic dynamics). These networks are required to perform significant processing tasks through collective local interaction that produces global properties.

Since the components and connections and their packaging under stringent spatial constraints make the system large-scale, the role of graph theory, algorithm, and neuroscience is pervasive. [7]

2.1.5 Perceptron:

At the heart of every Neural Network is what is referred to as the perceptron (sometimes called processing element or neural node) which is analogus to the neuron nucles in the brain. The second layer that is very first hidden layer is known as perceptron. As was the case in the brain the operation of the perceptron is very simple; however also as is the case in the brain, when all connected neurons operate as a collective they can provide some very powerful learning capacity.

Input signals are applied to the node via input connection (dendrites in the case of the brain.) The connections have “strength” which changes as the system learns. In neural networks the strength of the connections are

referred to as weights. Weights can either excite or inhibite the transmission of the incoming signal. Mathematically incoming signals values are multiplied by the value of those particular weights.

At the perceptron all weighted input are summed. This sum value is than passed to a scaling function. The selection of scaling function is part of the neural network design. [9]

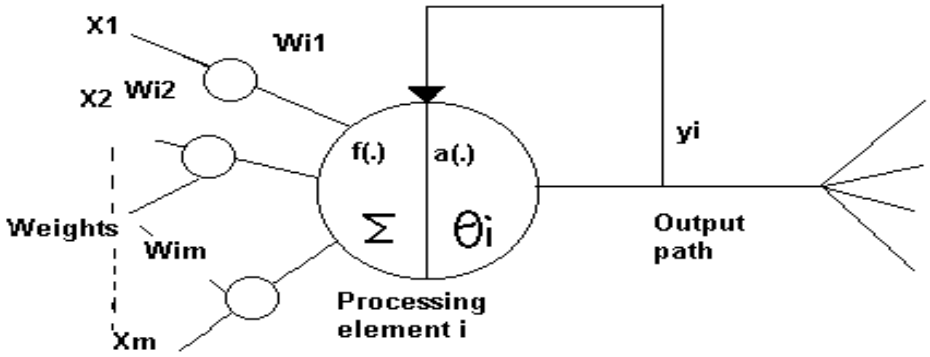

Figure (2.3): Perceptron [5]

2.1.6 Basic Structure of artificial neural network

2.1.6.1 Input layer:

The bottom layer is known as input neuron network in this case x1 to x5 are output neurons input layer neurons.

2.1.6.2 Hidden layer:

The in-between input and output layer the layers are known as hidden layers where the knowledge of past experience

2.1.6.3 Output Layer:

The top most layer which give the final output. In this case z1 and z2 are [9]

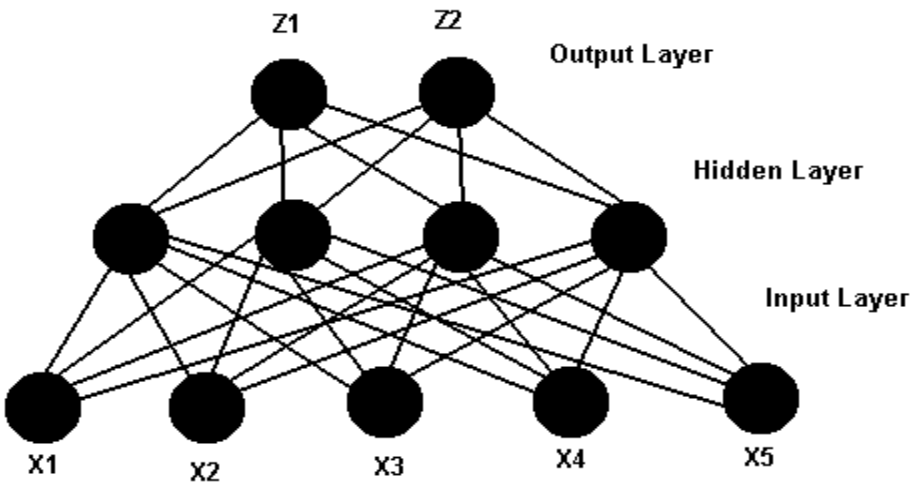

Figure (2.4): Basic structure of Artificial Neural Network [9]

2.1.7 Network architectures

1). Single layer feed forward networks:

In this layered neural network the neurons are organized in the form of layers.

In this simplest form of a layered network, we have an input layer of source nodes those projects on to an output layer of neurons, but not vise-versa. In other words, this network is strictly a feed forward or acyclic type [5]. It is as shown in figure:

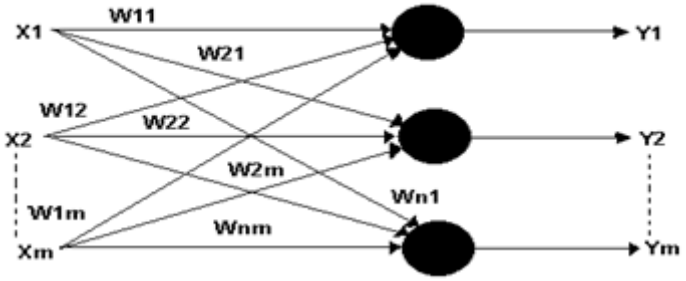

Figure (2.5): Single –layer feed forward Network [6]

Such a network is called single layered network, with designation “single later” referring to the o/p layer of neurons.

2). Multilayer feed forward networks: The second class of the feed forward neural network distinguishes itself by one or more hidden layers, whose computation nodes are correspondingly called neurons or units. The function of hidden neurons is intervenue between the external i/p and the network o/p in some useful manner. The ability of hidden neurons is to extract higher order statistics is particularly valuable when the size of i/p layer is large.

The i /p vectors are feed forward to 1st hidden layer and this pass to 2nd hidden layer and so on until the last layer i.e. output layer, which give actual network response [5].

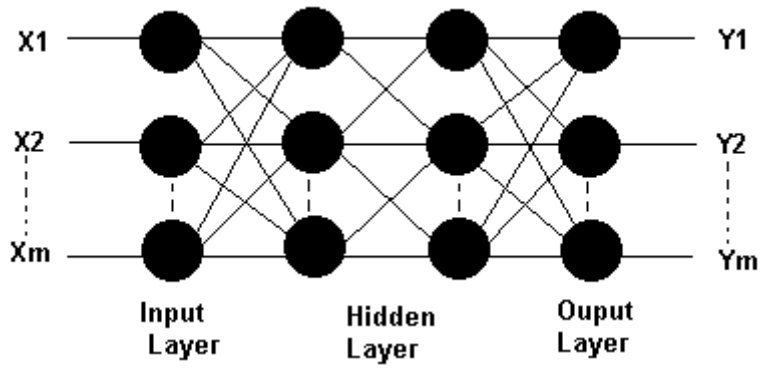

Figure (2.6): Multilayer feed forward network [5]

3). Recurrent networks:

A recurrent network distinguishes itself from feed forward neural network, in that it has least one feed forward loop. As shown in figures output of the neurons is fed back into its own inputs is referred as self-feedback

A recurrent network may consist of a single layer of neurons with each neuron feeding its output signal back to the inputs of all the other neurons. Network may have hidden layers or not.

Figure (2.7): Single node with feedback to it self [5]

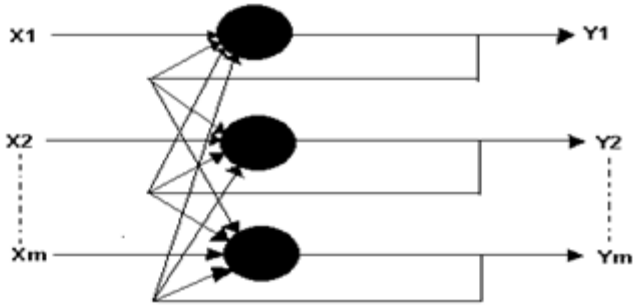

Figure (2.8) Multilayer recurrent network [5]

2.1.8 Training of ANN

2.1.8.1 Supervised training

- Supplies the neural network with the input and desired output.

- Response of the network is measured.

2.1.8.2 Unsupervised training

- Only supplies input without desired output.

- The neural network adjusts its own weighs so that similar input causes similar output [7].

2.1.9 Advantages of Neural Networks

1) Networks start processing the data without any preconceived hypothesis. They start random with weight assignment to various input

variables. Adjustments are made based on the difference between predicted and actual output. This allows for unbiased and batter understanding of data.

2) Neural networks can be retained using additional input variables and number of individuals. Once trained they can be called on to predict in a new patient.

3) There are several neural network models available to choose from in a particular problem.

4) Once trained, they are very fast.

5) Due to increased accuracy, results in cost saving.

6) Neural networks are able to represent any functions. Therefore they are called '**Universal Approximators**'.

7) Neural networks are able to learn representative examples by back propagating errors

2.1.10 Application of Artificial Neural Network

1. Classification

Pattern recognition, feature extraction, image matching.

2. Noise reduction

Recognize pattern in the input and produce noiseless outputs.

3. Prediction

Extrapolation based on historical data. [10]

2.2 Kidney failure disease

2.2.1 Introduction

Kidneys are the organs that help filter waste products from the blood. They are also involved in regulating blood pressure, electrolyte balance, and red blood cell production in the body.

There are numerous causes of kidney failure, and treatment of the underlying disease may be the first step in correcting the kidney abnormality.

Some causes of kidney failure are treatable and the kidney function may return to normal. Unfortunately, kidney failure may be progressive in other situations and may be irreversible.

Symptoms of kidney failure are due to the build-up of waste products in the body that may cause weakness, shortness of breath, lethargy, and confusion. Inability to remove potassium from the bloodstream may lead to abnormal heart rhythms and sudden death. Initially, there may be no symptoms of kidney failure.

The diagnosis of kidney failure usually is made by blood tests measuring BUN, creatinine, and glomerular filtration rate (GFR).

Treatment of the underlying cause of kidney failure may return kidney function to normal. Lifelong efforts to control blood pressure and diabetes may be the best way to prevent chronic kidney disease and its progression to kidney failure. Usually, kidney function gradually decreases over time.

If the kidneys fail completely, the only treatment options available may be dialysis or transplant. [11]

2.2.2 The kidneys

The kidneys play key roles in body function, not only by filtering the blood and getting rid of waste products, but also by balancing levels of electrolyte levels in the body, controlling blood pressure, and stimulating the production of red blood cells.

The kidneys are located in the abdomen toward the back, normally one on each side of the spine. They get their blood supply through the renal arteries directly from the aorta and send blood back to the heart via the renal veins to the vena cava. (The term "renal" is derived from the Latin name for kidney.)

The kidneys have the ability to monitor the amount of body fluid, the concentrations of electrolytes like sodium and potassium, and the acid-base balance of the body. They filter waste products of body metabolism, like urea from protein metabolism and uric acid from DNA breakdown. Two waste products in the blood can be measured: blood urea nitrogen (BUN) and creatinine (Cr).

When blood flows to the kidney, sensors within the kidney decide how much water to excrete as urine, along with what concentration of electrolytes. For example, if a person is dehydrated from exercise or from an illness, the kidneys will hold onto as much water as possible and the urine becomes very concentrated. When adequate water is present in the body, the urine is much more dilute, and the urine becomes clear. This system is controlled by renin, a hormone produced in the kidney that is part of the fluid and blood pressure regulation systems of the body.

Kidneys are also the source of erythropoietin in the body, a hormone that stimulates the bone marrow to make red blood cells. Special cells in the kidney monitor the oxygen concentration in blood. If oxygen levels fall,

erythropoietin levels rise and the body starts to manufacture more red blood cells.

After the kidneys filter blood, the urine is excreted through the ureter, a thin tube that connects it to the bladder. It is then stored in the bladder awaiting urination, when the bladder sends the urine out of the body through the urethra. [11]

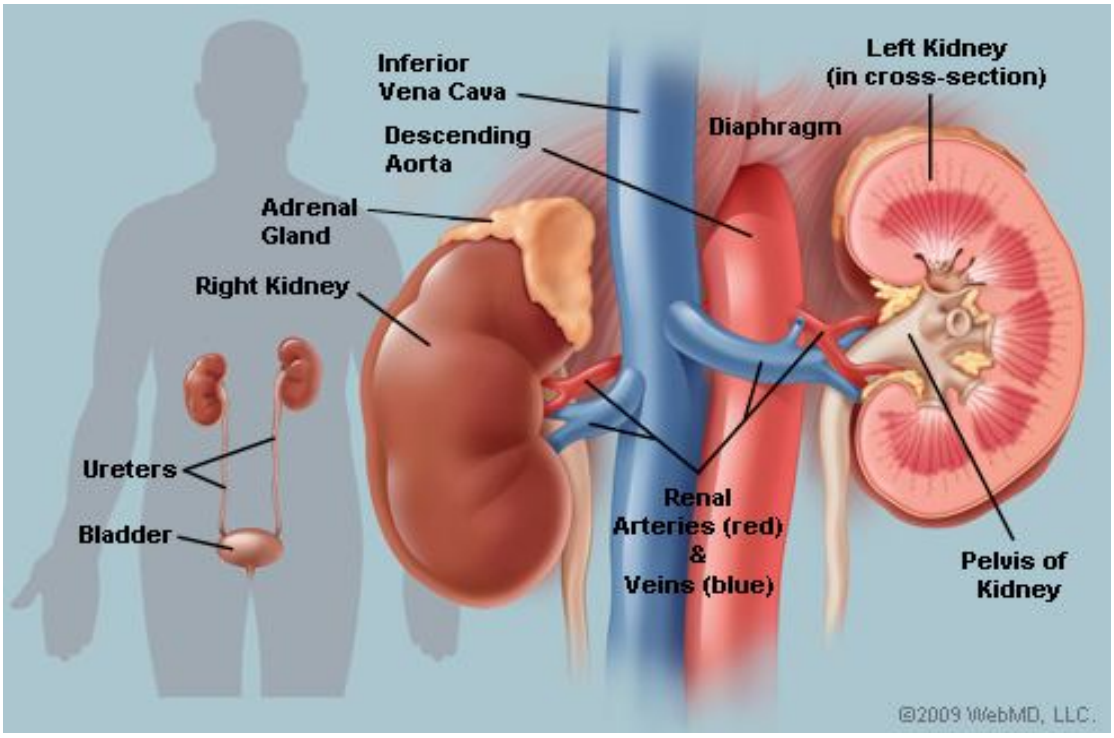

Figure (2.9): The kidney [12]

2.2.3 Causes of kidney failure

Kidney failure can occur from an acute situation or from chronic problems.

2.2.3.1 Acute renal failure

Kidney function is lost rapidly and can occur from a variety of insults to the body. The list of causes is often categorized based on where the injury has occurred. [11]

2.2.3.1.1 Prerenal causes

Causes are due to decreased blood supply to the kidney. Examples of prerenal causes of kidney failure are:

hypovolemia (low blood volume) due to blood loss; dehydration from loss of body fluid (for example, vomiting, diarrhea, sweating ,fever);

poor intake of fluids; medication, for example, diuretics ("water pills") may cause excessive water loss; and abnormal blood flow to and from the kidney due to obstruction of the renal artery or vein. [11]

2.2.3.1.2 Renal causes of kidney failure

Damage directly to the kidney itself) include:

Sepsis: The body's immune system is overwhelmed from infection and causes inflammation and shutdown of the kidneys. This usually does not occur with urinary tract infections.

Medications: Some medications are toxic to the kidney, including nonsteroidal anti-inflammatory drugs like ibuprofen and naproxen. Others potentially toxic medications include antibiotics like aminoglycosides [gentamicin (Garamycin), tobramycin], lithium (Eskalith, Lithobid), iodine-containing medications such as those injected for radiology dye studies.

Rhabdomyolysis: This is a situation in which there is significant muscle breakdown in the body, and the damaged muscle fibers clog the filtering system of the kidneys. This can occur because of trauma, crush injuries, and burns. Some medications used to treat high cholesterol can cause rhabdomyolysis. [11]

Multiple myeloma

Acute glomerulonephritis or inflammation of the glomeruli, the filtering system of the kidneys. Many diseases can cause this inflammation

including systemic lupus erythematosus, Wegener's granulomatosis, and Goodpasture syndrome. [11]

2.2.3.1.3 Post renal

Are due to factors that affect outflow of the urine:

Obstruction of the bladder or the ureters can cause back pressure because the kidneys continue to produce urine, but the obstruction acts like a dam, and urine backs up into the kidneys. When the pressure increases high enough, the kidneys are damaged and shut down.

Prostatic hypertrophy or prostate cancer may block the urethra and prevents the bladder from emptying.

Tumors in the abdomen that surround and obstruct the ureters.

Kidney stones. Usually, kidney stones affect only one kidney and do not cause kidney failure. However, if there is only one kidney present, a kidney stone may cause the lone kidney to fail. [1]

2.2.3.2 Chronic renal failure

Develops over months and years. The most common causes of chronic renal failure are related to: poorly controlled diabetes, poorly controlled high blood pressure, and chronic glomerulonephritis.

Less common causes of chronic renal failure include:

Polycystic kidney disease, reflux nephropathy, kidney stones, and prostate disease. [13]

2.2.4 Symptoms of kidney failure

In the beginning, kidney failure may be asymptomatic (not producing any symptoms). As kidney function decreases, the symptoms are related to the inability to regulate water and electrolyte balances, to clear waste products from the body, and to promote red blood cell production.

Lethargy, weakness, shortness, and generalized swelling may occur.

Unrecognized or untreated, life-threatening circumstances can develop. Metabolic acidosis, or increased acidity of the body due to the inability to manufacture bicarbonate, will alter enzyme and oxygen metabolism, causing organ failure.

Inability to excrete potassium and rising potassium levels in the serum (hyperkalemia) is associated with fatal heart rhythm disturbances (arrhythmias) including ventricular tachycardia and ventricular fibrillation.

Rising urea levels in the blood (uremia) can affect the function of a variety of organs ranging from the brain (encephalopathy) with alteration of thinking, to inflammation of the heart lining (pericarditis), to decreased muscle function because of low calcium levels (hypocalcemia).

Generalized weakness may be due to anemia, a decreased red blood cell count, because lower levels of erythropoietin produced by failing kidneys do not adequately stimulate the bone marrow. A decrease in red cells equals a decrease in oxygen-carrying capacity of the blood, resulting in decreased oxygen delivery to cells for them to do work; therefore, the body tires quickly. As well, with less oxygen, cells more readily use anaerobic metabolism (an=without + aerobic=oxygen) leading to increased amounts of acid production that cannot be addressed by the already failing kidneys.

As waste products build in the blood, loss of appetite, lethargy, and fatigue become apparent. This will progress to the point where mental function will decrease and coma may occur.

Because the kidneys cannot address the rising acid load in the body, breathing becomes more rapid as the lungs try to buffer the acidity by blowing off carbon dioxide. Blood pressure may rise because of the

excess fluid, and this fluid can be deposited in the lungs, causing congestive heart failure. [14]

2.2.5 Diagnosis of kidney failure

Diagnosis of kidney failure is confirmed by blood tests measuring the buildup of waste products in the blood. BUN, creatinine, and GFR are routine blood tests used to measure the buildup of waste products in the blood. BUN and creatinine become elevated, and the glomerular filtration rate (GFR) decreases. This is the rate with which blood is filtered through the kidneys and can be calculated based upon the creatinine level, age, race, and gender.

Urine tests may be done to measure the amount of protein, detect the presence of abnormal cells, or measure the concentration of electrolytes. Protein in the urine is not normal and can be a clue that damage to the kidneys has occurred. When the urine is examined under a microscope, abnormal aggregations of red and white blood cells called casts can be seen in the urine with kidney disease. Comparing the concentrations of electrolytes in the blood and urine can help decide whether the kidneys are able to appropriately monitor and filter blood.

Other tests are used to diagnose the type of kidney failure. Abdominal ultrasound can assess the size of the kidneys and may identify whether any obstruction exists. Biopsy of the kidney uses a thin needle that is placed through the skin into the kidney itself to get bits of tissue to examine under the microscope. [15]

2.2.6 Treatment of kidney failure

Prevention is always the goal with kidney failure. Chronic diseases such as hypertension and diabetes are devastating because of the damage that they can do to kidneys and other organs. Lifelong diligence is important in keeping blood sugar and blood pressure within normal limits. Specific treatments are dependent upon the underlying diseases.

Once kidney failure is present, the goal is to prevent further deterioration of renal function. If ignored, the kidneys will progress to complete failure, but if underlying illnesses are addressed and treated aggressively, kidney function can be preserved, though not always improved. [11]

2.2.6.1 Dialysis

Dialysis cleanses the body of waste products in the body by use of filter systems. There are two types of dialysis; 1) hemodialysis, and 2) peritoneal dialysis. [11]

2.2.6.1.1 Hemodialysis

Hemodialysis uses a machine filter called a dialyzer or artificial kidney to remove excess water and salt, to balance the other electrolytes in the body, and to remove waste products of metabolism. Blood is removed from the body and flows through tubing into the machine, where it passes next to a filter membrane. A specialized chemical solution (dialysate) flows on the other side of the membrane. The dialysate is formulated to draw impurities from the blood through the filter membrane. Blood and dialysate never touch in the artificial kidney machine.

For this type of dialysis, access to the blood vessels needs to be surgically created so that large amounts of blood can flow into the machine and back to the body. Surgeons can build a fistula, a connection between a large artery and vein in the body, usually in the arm, that causes a large

amount of blood flow into the vein. This makes the vein larger and its walls thicker so that it can tolerate repeated needle sticks to attach tubing from the body to the machine. Since it takes many weeks for a fistula to mature enough to be used, significant planning is required if hemodialysis is to be considered as an option.

If the kidney failure happens acutely and there is no time to build a fistula, special catheters may be inserted into the larger blood vessels of the arm, leg, or chest. These catheters may be left in place for up to three weeks. In some diseases, the need for dialysis will be temporary, but if the expectation is that dialysis will continue for a prolonged period of time, these catheters act as a bridge until a fistula can be planned, placed, and matured.

Dialysis treatments normally occur three times a week and last a few hours at a time. Most commonly, patients travel to an outpatient center to have dialysis, but home dialysis therapy is becoming an option for some. [11]

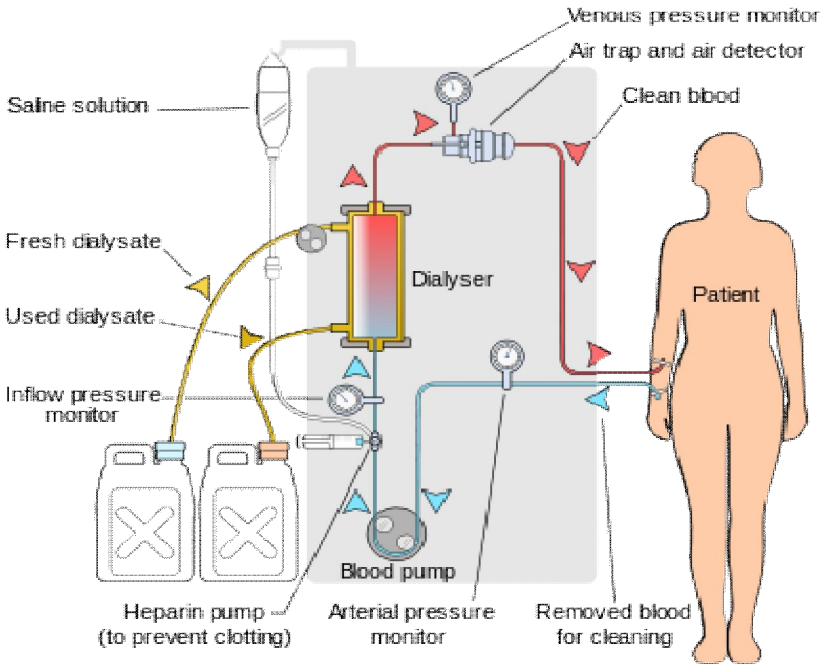

Figure (2.10): Hemodialysis [16]

2.2.6.1.2 Peritoneal dialysis

Peritoneal dialysis uses the lining of the abdominal cavity as the dialysis filter to rid the body of waste and to balance electrolyte levels. A catheter is placed in the abdominal cavity through the abdominal wall by a surgeon and is expected to remain there for the long-term. The dialysis solution is then dripped in through the catheter and left in the abdominal cavity for a few hours and then is drained out. In that time, waste products leech from the blood normally flowing through the lining of the abdomen (peritoneum).

There are benefits and complications for each type of dialysis. Not every patient can choose which type he or she would prefer. The treatment decision depends on the patient's illness and their past medical history along with other issues. Usually, the nephrologist (kidney specialist) will have a long discussion with the patient and family to decide what will be the best option available.

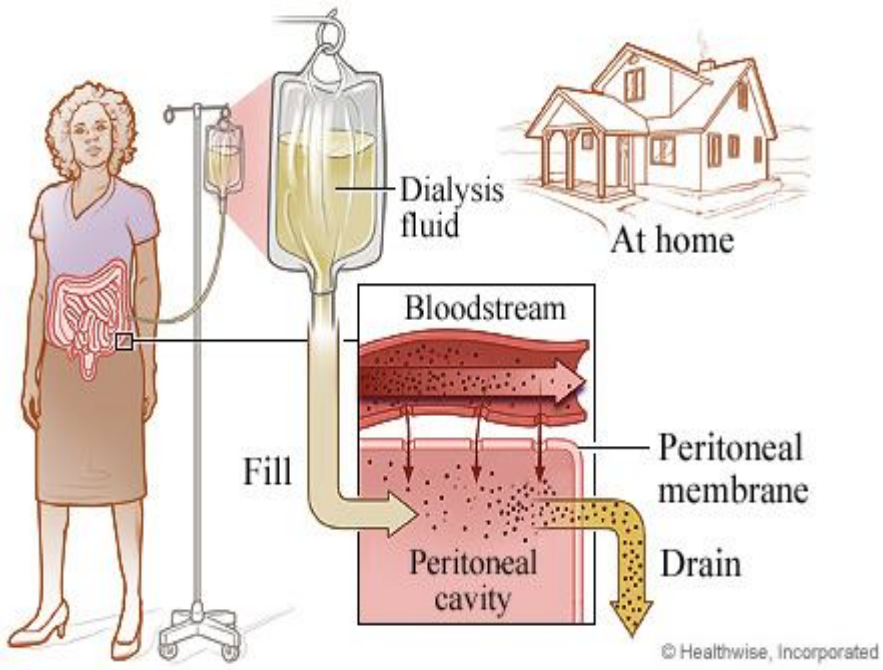

Figure (2.11): Peritoneal dialysis [12]

Dialysis is life saving. Without it, patients whose kidneys no longer function would die relatively quickly due to electrolyte abnormalities and the buildup of toxins in the blood stream. Patients may live many years with dialysis but other underlying and associated illnesses often are the cause of death. [11]

2.2.6.2 Kidney transplantation

If kidney failure occurs and is non-reversible, kidney transplantation is an alternative option to dialysis. If the patient is an appropriate candidate, the health care practitioner will contact an organ transplant center to arrange evaluation to see if the patient is suitable for this treatment. If so, the search for a donor begins. Sometimes, family members have compatible tissue types and, if they are willing, may donate a kidney. Otherwise, the patient will be placed on the organ transplant list that is maintained by the United Network of Organ Sharing.

Not all hospitals are capable of performing kidney transplants. The patient may have to travel to undergo their operation. The most successful programs are those that do many transplants every year.

While kidney transplants have become more routine, they still carry some risk. The patient will need to take anti-rejection medications that reduce the ability of the immune system to fight infection. The body can try to reject the kidney or the transplanted kidney may fail to work. As with any operation, there is a risk of bleeding and infection.

Kidney transplants may provide better quality of life than dialysis. After one year, 95% of transplanted kidneys are still functioning and after five years the number is 80%. It seems that the longer a patient is on dialysis, the shorter the life of the transplanted kidney.

If the transplanted kidney fails, the alternative is another kidney transplant or a return to dialysis. [11]

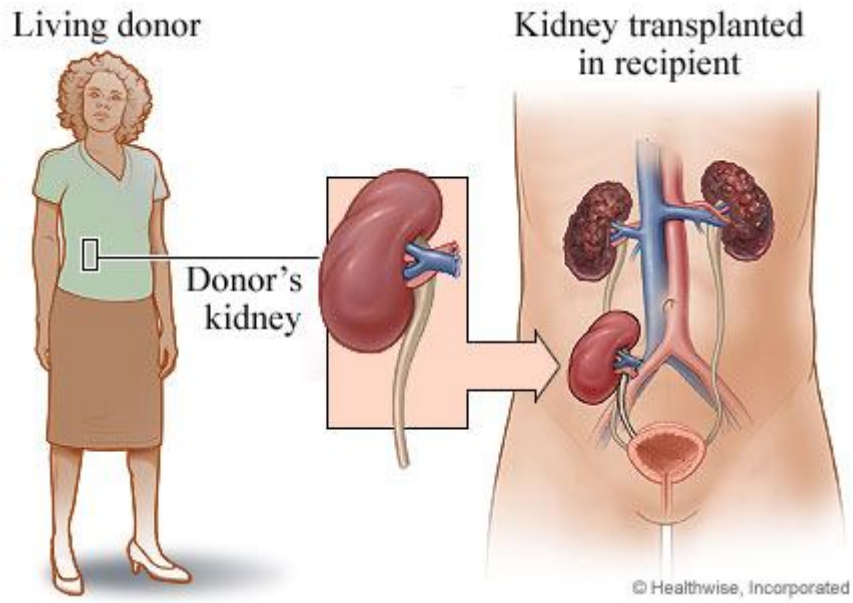

Figure (2.12): Kidney transplantation [12]

2.2.7 People who have a blood test of kidney function

Routine kidney function is one of the most commonly performed blood tests. It may be done:

1. as part of a general health assessment.

2. If you have suspected dehydration (when the urea level increases).

3. If you have suspected kidney failure. The higher the blood levels of urea and creatinine, the less well the kidneys are working. The level of creatinine is usually used as a marker as to the severity of kidney failure. (Creatinine in itself is not harmful, but a high level indicates that the kidneys are not working properly. So, many other waste products will not be cleared out of the bloodstream.) You normally need treatment with dialysis if the level of creatinine goes higher than a certain value.

4. before and after starting treatment with certain medicines. Some medicines occasionally cause kidney damage as a side-effect. Therefore, kidney function is often checked before and after starting treatment with certain medicines. [17]

2.3 Historical background studies

(1): Ali Hussein Ali Al-Timemy [18].

This paper presents the prediction of Kidney dysfunction using probabilistic neural network (PNN). For each subject, Serum urea and Serum creatinin levels have been analyzed and tested by using clinical laboratory measurements. The collected Urea and creatinine levels are then used as inputs to the Artificial Neural network model in which the training process is done by PNN which is a class of radial basis function (RBF) network is used as a classifier to predict whether Kidney is normal or it will have a dysfunction. The accuracy of Prediction, sensitivity and Specificity were found to be equal to 99%, 98% and 99% respectively for this proposed network.

(2): Rajalakshmi M, Neelamegam P and Bharathi N [19].

This paper presents an efficient and effective model of forecast and classification of functional abnormalities of kidney using Associative Neural Network (ASNN) and Polynomial Neural Network (PNN). The ASNN and PNN are constructed with neurons arranged in such a way that the network consists of ten, eight and one neurons in the input, hidden and output layers respectively. Glomerular Filtration Rate (GFR) which can indicate the efficiency of functionality of kidneys is arrived using Modification of Diet in Renal Disease (MDRD) formula and the network is trained with these data sets. The trained ASNN and PNN are used for

testing and used as an effective model for the forecast, categorization of renal functional abnormalities and severity level of CKD. The result of this study shows that ASNN provides satisfactory results for the diagnosis and classification of kidney dysfunction with excellent correlation co-efficient (R^2 = 0.987) for training and 0.951 for testing. In the end part the results are cross validated by Leave-One-Out (LOO) procedure. Correlation coefficient of 0.955for training and 0.958 for testing confirms the classification ability of PNN.

(3): Michael E. Brier, Prasun C. Ray and Jon B. Klein [20]

In this study, an artificial neural network was used to predict the occurrence of DGF and compared with traditional logistical regression models for prediction of DGF.

Covariate analysis by artificial neural networks and traditional logistical regression were done to predict the occurrence of DGF.

The incidence of DGF in this study was 38%. Logistic regression analysis was more sensitive to prediction of no DGF (91 *vs* 70%), while the neural network was more sensitive to prediction of yes for DGF (56 *vs*37%). Overall prediction accuracy for both logistic regression and the neural network was 64 and 63%, respectively. Logistic regression was 36.5% sensitive and 90.7% specific. The neural network was 63.5% sensitive and 64.8% specific. The only covariate with a $P < 0.001$ was the transplant of a white donor kidney to a black recipient. Cox proportional hazard regression was used to test for the negative effect of DGF on long-term graft survival. One year graft survival in patients without DGF was 92 ± 2% *vs* 81 ± 3% in patients with DGF. The 5-year graft survival was not affected by DGF in this study.

(4) Fariba Shadabi, Robert Cox and Dharmendra Sharma [21].

In this study we sought to use ANN to predict renal transplantation outcomes. Our results showed that although this was possible, the positive predictive power of the trained ANN was low, indicating a need for improvement if this approach is to be useful clinically. We also highlight potential problems that may arise when using incomplete clinical datasets for ANN training including the danger of pre-processing data in such a way that misleading high predictive value is obtained. [12]

Chapter Three

The Proposed System

3.1 Data set

The database used for prediction of kidney failure using artificial neural network is collected from many hospitals and hemodialysis centers. The database has been collected from 60 patients and used for this proposed system.

3.2 Attribute selection

The database has 60 patients and 7 attributes. Attribute 1 through 7 are used to represent patients. Each patient has one of two possible cases: normal and abnormal. According to the class distribution 20 are normal and 40 are abnormal. All attributes are shown in the table below.

Table (3.1): Attributes description

	Attribute	**The normal value**
1	Urea.	15-45mg/100ml
2	Creatinine	0.5-1.5mg/100ml
3	Potassium (K)	3.5-5.0mEq/L
4	Sodium (Na)	135-140mEq/L
5	Calcium (Ca)	8.6-10.3mEq/L
6	Phosphorus	2.5-5.0mg/100ml
7	Uric Acid.	2.0-7.0mg/100ml

3.3 Data processing

After selection of all attributes, attributes that contain missing value were gotten rid.

The second step original data is transformed to (massage) using the simple equation shown below:

(Original value-lower bound)/ (upper bound-lower bound+1)…. (1)

3.4 Artificial Neural Network model

For building neural network model there are two main steps:

1. Create the neural network.

2. Train and test the neural network

3.4.1 Create Neural Network

MATLAB software package version 10 is used to implement the software for the current work. The data was input to the neural network from the work space. Data were randomly divided into a training sample (20 cases) and a test sample (40 cases).

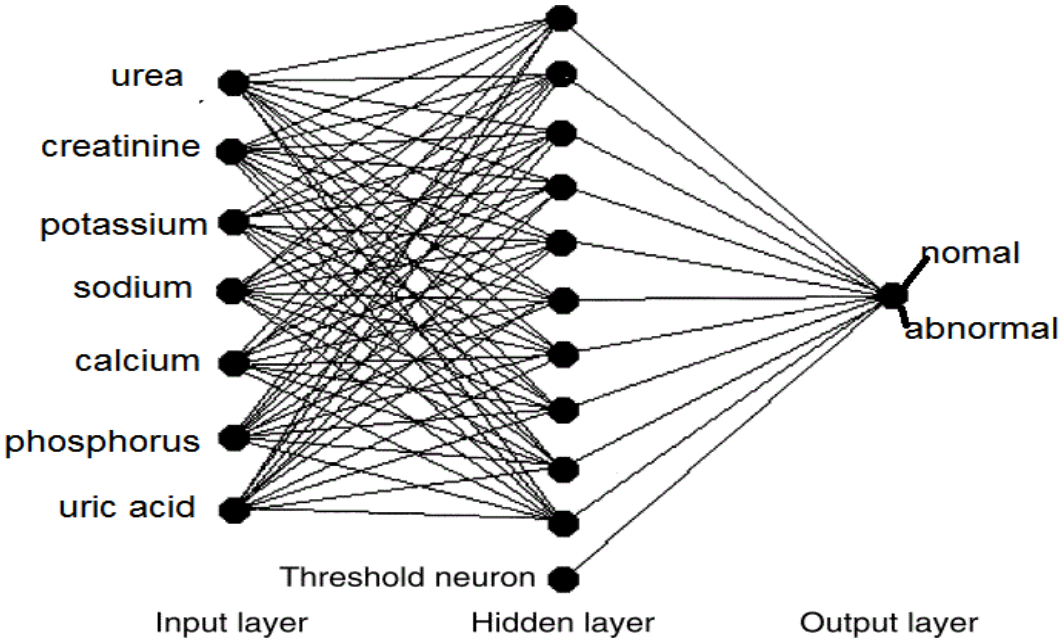

Figure (3.1) Architecture of ANN using for prediction of kidney failure

3.4.2 Training and Testing of ANN Network

3.4.2.1 Feed Forward Back propagation Network

Feed forward back propagation artificial neural network model shown in figure (4.1) consists of input, hidden and output layers. Back propagation learning algorithm was used for learning these networks.

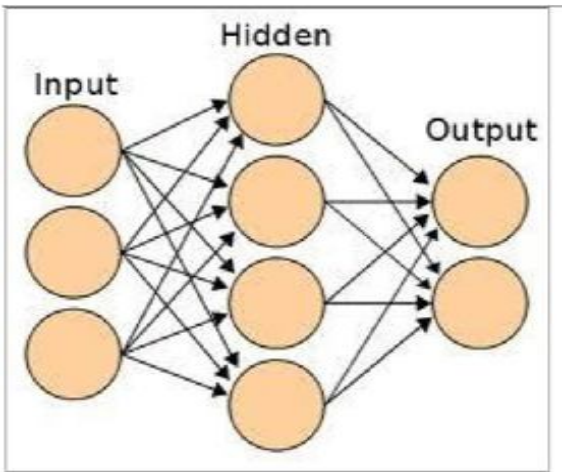

Figure (3.2) Feed Forward Back propagation Network

During training this network, calculations were carried out from input layer of network toward output layer, and error values were then propagated to prior layers. Feed forward networks often have one or more hidden layers of sigmoid neurons followed by an output layer of linear neurons. Multiple layers of neurons with nonlinear transfer functions allow the network to learn nonlinear and linear relationships between input and output vectors. The outputs of a network such as between 0 and 1 are produced, then the output layer should use a sigmoid transfer function (tansig**).**

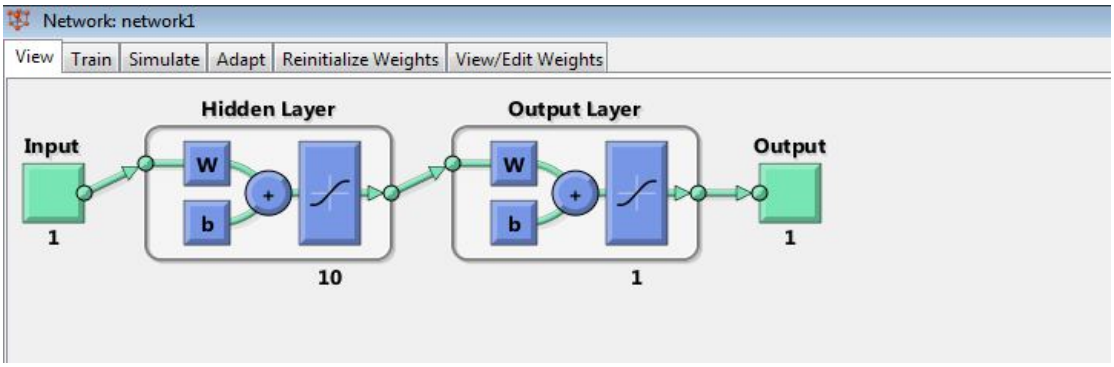

Figure (3.3) training of Feed Forward Back propagation Network

3.4.2.2 Cascade Forward Back propagation Network

Cascade forward back propagation model shown in figure(4.2) is similar to feed-forward networks, but include a weight connection from the input to each layer and from each layer to the successive layers. While two-layer feed forward networks can potentially learn virtually any input output relationship, feed-forward networks with more layers might learn complex relationships more quickly.

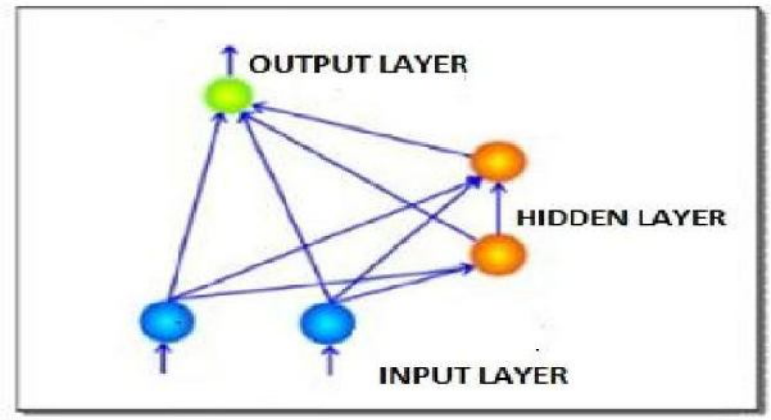

Figure (3.4) Cascade Forward Back propagation Network

Cascade forward back propagation ANN model is similar to feed forward back propagation neural network in using the back propagation algorithm for weights updating, but the main symptom of this network is that each layer of neurons related to all previous layer of neurons.

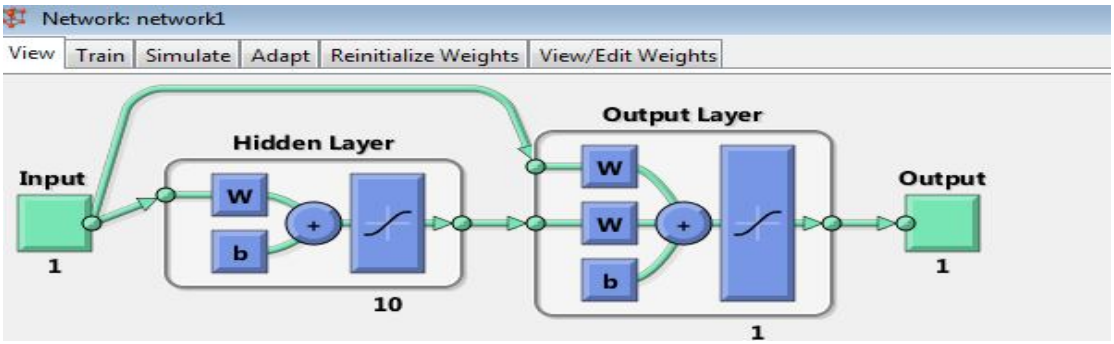

Figure (3.5) training of Cascade Forward Back propagation Network

3.5: Target used to training ANN

Table (3.2): Target

Urea	Creatinine	Potassium	Sodium	Calcium	Phosphorus	Uric Acid
0.48	0.18	0.30	0.32	0.31	0.36	0.41

The performance of cascade forward back propagation and feed forward back propagation were evaluated. The data set having seven input and one target is divided as training and testing as 20 used for training and 40 for testing to develop different models in Feed forward back propagation and Cascade forward back propagation. The results are in the next chapter.

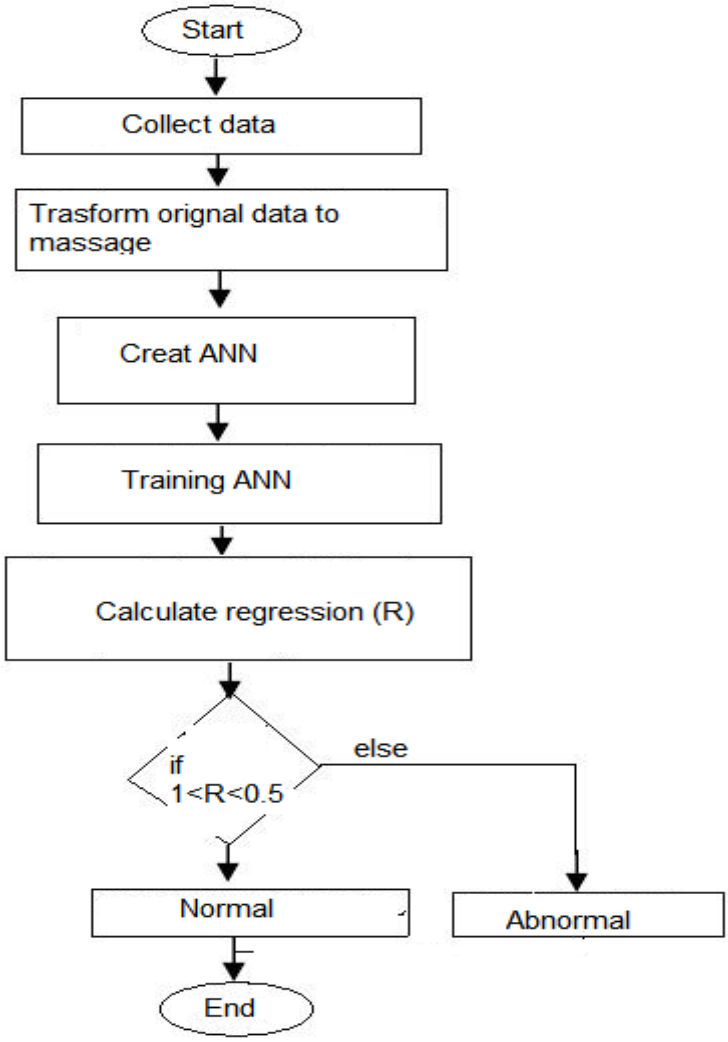

Figure (3.6) Flow diagrams for creating and training of a neural network

Chapter four

Results and Discussion

4.1 Results

Medical diagnosis by neural network is the black – box approach. Cascade Forward Back propagation and Feed Forward Back propagation were evaluated represent an efficient tool for the diagnosis of kidney failure disease. The ANN is trained with 7 inputs. After successful training, the system is able to diagnosis the unknown cases and make prediction.

4.1.1Abnormal patients

Table (4.1): Data of abnormal patients

NO	Urea	Creatinine	Potassium	Sodium	Calcium	Phosphorus	Uric Acid
1	1.39	6.55	4.00	0.36	-1.52	0.46	0.31
2	2.91	1.95	2.00	-0.36	0.56	0.80	0.73
3	2.38	2.05	1.40	0.09	-0.37	0.39	0.58
4	7.68	5.80	7.00	0.27	0.37	1.06	0.25
5	2.39	4.30	1.40	-0.18	-0,44	0.91	0.49
6	8.93	3.18	1.40	-0.18	0.04	0.94	0.87
7	5.07	4.75	2.40	0.18	-1.89	0.28	0.31
8	6.19	5.85	1,40	-0.45	0.37	0,80	0.56
9	2.16	2.65	1.20	-0.27	0.18	0.49	0.13
10	2.16	8.85	-1.40	-0.09	-2.00	2.77	0.69
11	5.45	5.20	6.00	0.18	0.74	0.69	0.43
12	2.71	5.15	3.00	0.18	0.29	1.23	0.25
13	3.17	4.90	4.40	0.00	-0.52	1.08	0.31
14	5.00	4.30	2.00	0.09	-0.74	0.00	0.82

15	2.32	1.80	2.20	0.00	-0.11	0.40	0.54
16	2.32	3.00	2.00	0.27	0.04	0.63	0.42
17	1.97	2.80	2.00	0.36	1.29	0.68	0.76
18	2.71	2.60	-1.40	0.09	1.00	0.80	0.62
19	9.58	6.60	-0.40	0.45	0.04	1.80	0.40
20	2.71	2.60	-1.40	0.09	1.00	0.80	0.62
21	9.58	6.60	-0.40	-0.45	0.04	1.80	0.40
22	2.71	2.60	-1.40	0.09	1.00	0.80	0.62
23	13.32	6.90	2.20	-0.18	-0.93	3.06	1.73
24	4.29	4.90	-0.40	-2.27	-0.48	0.34	0.09
25	3.89	5.45	2.60	-0.09	0.07	0.60	0.80
26	2.03	3.75	2.00	0.09	0.29	0.71	0.58
27	9.00	12.00	3.40	-0.09	0.26	1.71	0.82
28	2.42	1.85	2.60	0.18	0.04	0.63	0.69
29	5.32	3.90	4.00	-0.36	-0.19	1.17	0.57
30	2.81	1.30	1.00	0.09	0.07	0.46	0.44
31	5.58	6.45	5.20	-0.27	0.33	0.34	0.47
32	2.61	2.00	1.00	0.45	0.22	1.77	0.69
33	1.32	2.25	2.20	-0.45	0.26	0.77	0.31
34	13.71	10.75	0.80	0.27	0.11	2.37	0.60
35	4.42	3.65	2.80	0.00	-0.29	0.68	0.40
36	2.29	2.95	1.40	0.36	0.59	0.23	0.11
37	3.11	4.65	4.40	0.45	-0.18	0.37	0.56
38	3.74	4.30	1.80	0.18	0.48	0.29	1.24
39	4.29	2.40	3.00	0.82	0.48	1.00	1.13
40	3.06	5.75	1.80	-0.18	-0.67	0.80	0.38

Table (4.1) shows the data of abnormal patients. The original data is transformed (massaged) using the simple equation shown below:

(originalvalue -lowerbound)/(uppernound – lowerbound + 1)

The massaged value was used to train the system since it's in the format recognized by the system.

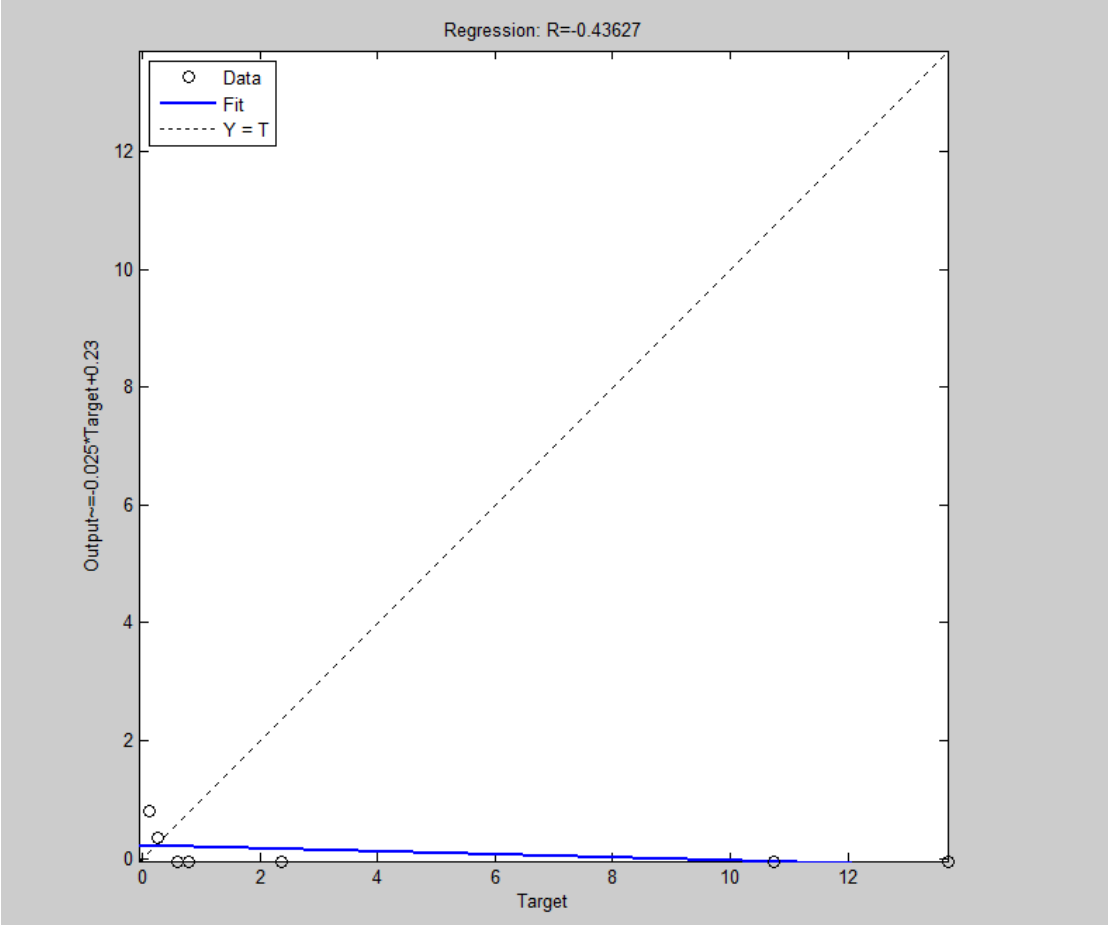

Figure (4.1): Abnormal patient regressions

The above figure shows the regression of abnormal patient which is equal to 0.43. The range of abnormal is between (0 to 0.5). Also we got about 2 patients outside the range but have the same figure with patient inside the range.

Table (4.2): Abnormal patient regression

Patient number	Regression value FFB	Regression value CFB
1	0,11	0.11
2	0.08	0.08
3	0.15	0.07
4	0.17	0.09
5	0.16	0.15

6	0.16	0.16
7	0.11	0.17
8	0.09	0.15
9	0.10	0.10
10	0.27	0.27
11	0.03	0.03
12	0.02	0.09
13	0.15	0.09
14	0.07	0.07
15	0.15	0.07
16	0.12	0.08
17	0.08	0.08
18	0.19	0.19
19	0.20	0.01
20	0.19	0.19
21	0.24	0.04
22	0.19	0.19
23	0.16	0.16
24	0.01	0.05
25	0.16	0.16
26	0.13	0.15
27	0.14	0.16
28	0.16	015
29	0.16	0.15
30	0.14	0.12
31	0.03	0.05
32	0.14	0.13
33	0.12	0.09
34	0.16	0.16
35	0.13	0.08
36	0.38	0.26
37	0.13	0.02

38	0.05	0.01
39	0.13	0.13
40	0.13	0.09

Table (4.2) describes the regression of 40 abnormal patients. The regression values get close to 0. P-value was calculated (p=0.959).

4.1.2 Normal person

Table (4.3): Data of normal person

NO	Urea	Creatinine	Potassium	Sodium	Calcium	Phosphorus	Uric Acid
1	0.52	0.15	0.24	0.36	0.25	0.48	0.43
2	0.46	0.13	0.25	0.27	0.33	0.34	0.49
3	0.42	0.17	0.30	0.36	0.22	0.22	0.40
4	0.53	0.20	0.32	0.27	0.41	0.40	0.43
5	0.60	0.18	0.27	0.45	0.29	0.34	0.36
6	0.39	0.21	0.28	0.18	0.33	0.46	0.51
7	0.57	0.16	0.31	0.45	0.22	0.37	0.31
8	0.45	0.22	0.29	0.36	0.25	0.40	0.40
9	0.51	0.25	0.26	0.27	0.29	0.46	0.49
10	0.43	0.19	0.30	0.45	0.48	0.26	0.43
11	0.48	0.17	0.32	0.54	0.33	0.22	0.31
12	0.37	0.18	0.28	0.36	0.41	0.34	0.49
13	0.63	0.23	0.27	0.27	0.29	0.41	0.34
14	0.42	0.22	0.32	0.36	0.22	0.45	0.43
15	0.38	0.13	0.29	0.45	0.33	0.34	0.40
16	0.41	0.22	0.30	0.27	0.25	0.40	0.49
17	0.37	0.17	0.29	0.36	0.48	0.34	0.40
18	0.29	0.19	0.27	0.45	0.29	0.40	0.34
19	0.36	0.21	0.32	0.27	0.41	0.28	0.43
20	0.31	0.16	0.28	0.36	0.22	0.34	0.52

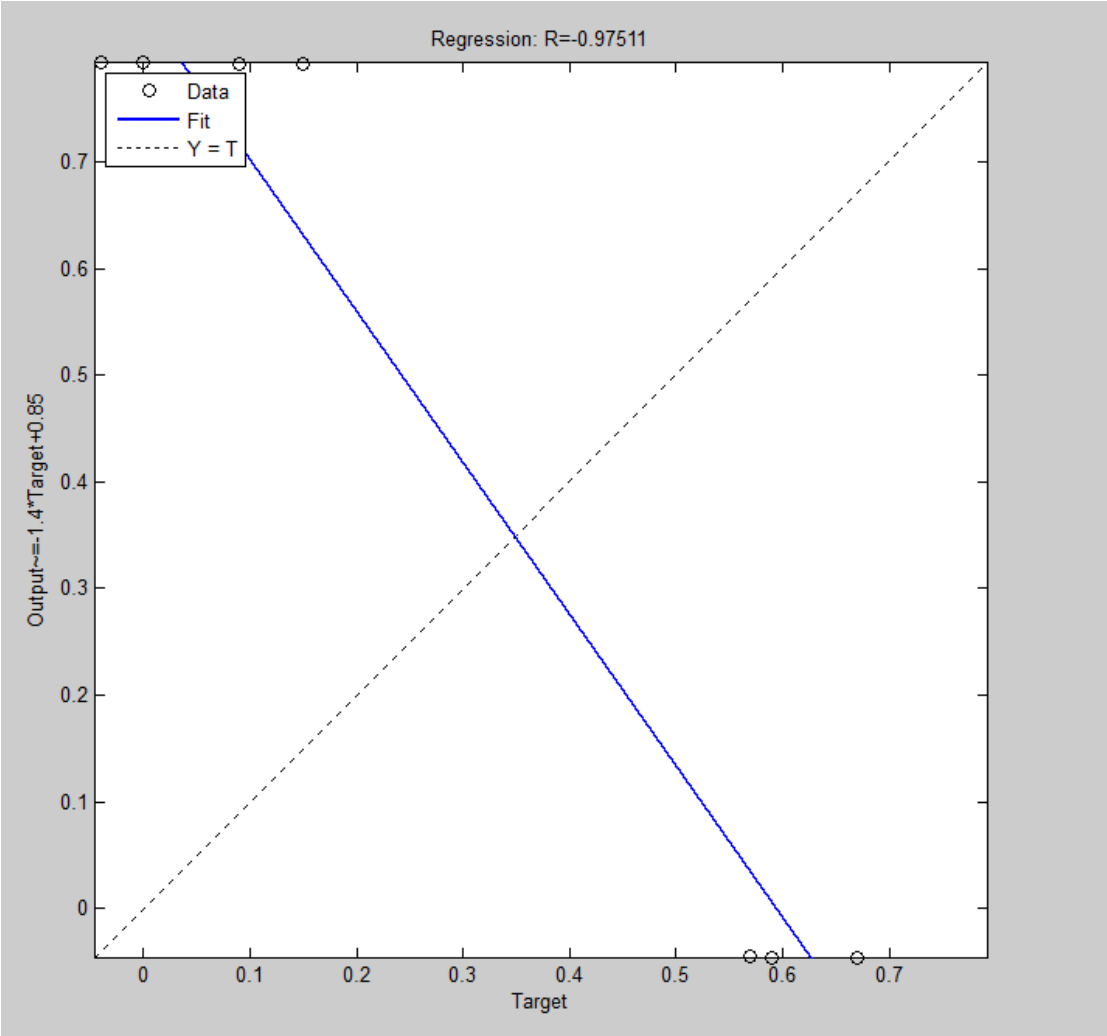

Figure (4.2): Normal person regressions

The above figure shows the regression of normal which is equal to 0.97. The range of abnormal is between (0.5 to 1).

Table (4.4): Normal person regression

Patient number	Regression value FFB	Regression value CFB
1	0.85	0.79
2	0.86	0.77
3	0.72	0.71
4	0.75	0.82

5	0.89	0.49
6	0.62	0.37
7	0.79	0.48
8	0.80	0.72
9	0.79	0.80
10	0.67	0.53
11	0.65	0.44
12	0.78	0.31
13	0.64	0.70
14	0.58	0.73
15	0.77	0.05
16	0.81	0.52
17	0.77	0.10
18	0.60	0.07
19	0.64	0.30
20	0.87	0.34

Table (4.4) describes the regression of 20 normal people as the table show there are a few patient have not classified will by the neural network. P-value was calculated (p=000018).

4.1.3 Performance evaluation of ANNS

Table (4.5) Results of comparative studies

	FFBP	CFBP
Sensitivity	97.5%	100%
Specificity	100%	85%
Accuracy	98.3%	95%

In Table (5.6) the classification accuracies obtained by two neural network techniques are compared for kidney failure database. The results show that the accuracies obtained by each neural network technique are quite compatible. The highest accuracy is given by BBFF (98.3%).

Sensitivity = True Positive / True Positive + False Negative…… (2)

Specificity = True Negative/ True Negative + False Positive…..….. (3)

Accuracy = (True Positive +True Negative)/ (True Positive+ False Positive + True Negative + False Negative……..... (4)

- True positive: Sick people correctly diagnosed as sick
- False positive: Healthy people incorrectly identified as sick
- True negative: Healthy people correctly identified as healthy
- False negative: Sick people incorrectly identified as health.

4.2 Discussion

The study for prediction of kidney failure has been carried out using Feed forward back propagation and Cascade forward back propagation algorithms.

The results of this study demonstrate that an ANN model with variables consisting of (urea, creatinine, potassium, sodium, calcium, phosphorus and uric acid) is classified a total of 60 of patients correctly to normal and abnormal.

There are many differences between normal and abnormal patient due to different between patients attributes which enable neural network to

recognize this difference, so the neural network can classifies the patient to normal and abnormal based in there attributes.

Back propagation trained algorithm is used to trained the neural network .Regression values R measure correlation between outputs and targets. An R value of one means a close relationship, 0 a random relationship. When regression gets close to 1 means patient is normal, when its get close to 0 means abnormal patient.

The small p-values obtained indicated that they are most significant predictor of kidney failure

The data set used in FFBNN is also applied to Cascade Forward Back propagation Network CFBNN for comparative study.

Chapter five

Conclusion and Recommendation

5.1 Conclusion

Artificial neural networks are often used as a powerful discriminating classifier for tasks in medical diagnosis. They have several advantages over parametric classifiers such as discriminate analysis. Acute and Chronic Renal failures or Kidney Diseases (CKD) are being observed as a serious challenge to the field of Medical and health industry with its impact on a mass population of the world.

This work presents a data mining technique for predicting the life expectancy of a kidney disease patient, dialysis survival and renal failure detection. The results obtained can be used by physicians in authenticating the accuracy of laboratory test results. In other words, this work demonstrates the applicability of data mining techniques such as ANNs in medical sciences.

In conclusion, an artificial neural network model with variables consisting of (urea, creatinine, potassium, sodium, calcium phosphorus, uric acid) may be useful for predicting of kidney failure.

5.2 Recommendations

The recommendations are

1. Increase the sample size to get more accurate result.

2. Use more artificial neural network model for comparison

References

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Appendix (A)

MATLAB code to get the regression

```
 net=setx(net,w);
y=sim(net,a1);
r=corrcoef(y,l);
R=r(1,2)
```

MATLAB code for data classification

```
fprintf('enter the data\n');
X=input('enter ur data as matrix');
X(1)=((x(1)-15)/(45-15+1));
X(2)=((x(2)-0.5)/(1.5-0.5+1));
X(3)=((x(3)-3.5)/(5-3.5+1));
X(4)=((x(4)-135)/(140-135+1));
X(5)=((x(5)-8.6)/(10.3-8.6+1));
X(6)=((x(6)-2.5)/(5-2.5+1));
X(7)=((x(7)-2)/(7-2+1));
net=setx(net,w);
y=sim(net,x);
r=corrcoef(x,y);
z=r(1,2)
R=abs(z)
If 1> R> 0.5
    disp('The patient is normal')
Else
    Disp('The patient is abnormal')
end
```

Appendix (B)

Equations

(Original value-lower bound)/ (upper bound-lower bound+1)…. (1)

Sensitivity = True Positive / True Positive + False Negative…… (2)

Specificity = True Negative/ True Negative + False Positive…..….. (3)

Accuracy = (True Positive +True Negative)/ (True Positive+ False Positive + True Negative + False Negative……..... (4)